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Does urban concentration mitigate CO_2 emissions? Evidence from China 1998–2008☆

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ABSTRACT

We provide evidence of first increasing and then decreasing CO_2 emission intensity as the degree of urban concentration increases, based on data from 25 provincial regions in China over the period 1998–2008. This evidence is consistent with the environmentally desirable urban concentration argument identified in recent literature. Our findings indicate the importance of the spatial organization of activities and people in addressing regional CO_2 emissions.

1. Introduction

China has experienced an unprecedented rate of urbanization over the past three decades (Henderson, 2009; McKinsey Global Institute, 2009). Accompanying such rapid process, China's energy consumption and air pollution have increased substantially. In 2009, the total energy consumption of China was roughly 2.9 billion tons of standard coal and total CO_2 emissions was 7.7 billion tons (Du, Wei, & Cai, 2012). Is the urbanization process blamed for such significant environmental consequences? What urban development policies can contribute to the reduction of pollution emissions in the future? To answer these questions, this paper investigates the link between urbanization and CO_2 emission intensity using China's 25 provincial data over the time period of 1998 and 2008. Specifically, we examine urbanization through urban concentration — the spatial concentration of cities within a given region.

Urban spatial organization is one of the key factors that influence energy consumption, and thus CO_2 emissions. The high concentration of people and economic activities in some locations can lead to scale economies, proximity and agglomeration that may decrease energy use and associated pollution. Some studies find that increasing urban density may facilitate the mitigation of CO_2 emissions by significantly reducing energy consumption in urban areas (Glaeser & Kahn, 2010; Kamal-Chaoui & Robert, 2009;

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Newman & Kenworthy, 1989). However, these studies ignore the impact of changes in industrial composition, technological advance and institutional reform on the role played by urban spatial concentration in CO_2 emissions. Initial urban concentration may produce more air pollutants as the natural-resource-based or heavy industries are dominant. As clean technology adopts and industrial structure shifts towards light consumer industries or services, ongoing urban concentration tends to give rise to less pollution emissions per unit of economic activity. In the context of China, the adoption of clean technology may be closely related to the manufacturing's plants ownership status (Zheng & Kahn, 2013). The managers of Chinese state-owned enterprises (SOEs) are regarded as political officials, and they may have fewer incentives to reduce pollution under the old promotion criteria emphasizing output and profit targets. However, ownership reform prompted by local market development can push the local industrial structure towards 'green performance'. Thus, we argue that the interplay of scale economies, technological advance, ownership reform and industrial composition can lead to a non-linear relationship between the degree of urban concentration and CO_2 emissions.

A key issue in our analysis is the measure of urban concentration. We employ four measures as proxies for urban concentration within a region. The first is Zipf's coefficient, which provides an overall measure of spatial inequality for the entire distribution of an urban population. The second is the spatial Hirschman–Herfindahl Index (denoted by HHI) based on the sum of squared shares of every city in a regional urban population. The third is the urban primacy index measured as the share of the largest city in a regional urban population. Since the spatial HHI contains squared shares, they may be dominated by the largest share, and thus highly correlated with the urban primacy index. The last is the spatial Gini coefficient, which is used to calculate the spatial inequality of a population across cities within a region.

The paper starts with a simple STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) model and investigates the fundamental sources of CO_2 emissions per unit of GDP in a region by incorporating the degree of urban concentration. It is found that CO_2 emissions in per unit of GDP increases with urban concentration, which conflicts with findings from other studies. We then employ a nonparametric method to investigate the relationship between CO_2 emissions per unit of GDP and urban concentration. The estimation result shows a robust pattern of first increasing and then decreasing CO_2 emissions per unit of GDP as urban concentration increases. Such bell-shaped relationship confirms that the effects of the interplay of scale economies, technological change, institutional reform and associated industrial composition on CO_2 emission intensity at different levels of urban concentration.

Our study contributes to several strands of studies. First, it enriches current literature on the economic efficiency of urban concentration. For example, Henderson (2003) has identified a non-monotonous impact of urban primacy on economic development, thus suggesting a range of values for optimal primacy levels below which urban concentration fosters rather than deters economic growth. Rather than focus on economic growth as Henderson did, we examine the environmental implications of urban concentration. Second, this paper is closely related to recent studies focusing on China's CO_2 emissions (Auffhammer & Carson, 2008; Du et al., 2012; He & Wang, 2012; Zheng & Kahn, 2013). These studies find that economic development, urbanization and industrial structure are the key driving forces behind CO_2 emissions in China. Moving beyond them, our paper investigates how the spatial concentration of economic activities affects CO_2 emission intensity using China's provincial level data as other variables are considered.

The analysis of the impact of urban concentration on pollution emission intensity in China carries significant policy implications. China's fast urbanization has not only brought about economic benefits but also introduced severe environmental challenges. Our findings suggest that policies to mitigate carbon dioxide emissions should include improving the efficiency of the spatial organization of cities, such as the adoption of better technique for environmental management.

The following sections are organized as follows: Section 2 provides the conceptual framework and measures of urban concentration. Section 3 presents data on CO_2 emissions and measures of urban concentration and other variables. Section 4 conducts the empirical analysis including both parametric estimations and nonparametric estimations. Section 5 briefly discusses the results and concludes.

2. Conceptual framework

To explore the relationship between CO_2 emission and urban concentration, we start with a simple STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) model[1] which can be expressed as follows:

$$y_{it}^{z} = \mathrm{f}^{z}\left(\mathrm{P}_{it}, \mathrm{A}_{it}, U_{it,} X_{it}\right) + u_{it}^{z}, \tag{1}$$

where i and t index province and year, respectively. y is the environmental impact which in our case is CO_2 emission intensity. P is population size. A is per capital consumption. X is a vector of other relevant control variables and u is the error term. The vector U is the vector of z different measures of urban concentration in this analysis, which is to be defined precisely in the following paragraph. The STIRPAT model is then estimated in a semi-log-linear specification as the following:

$$y_{it}^{z} = \alpha_{z0} + \alpha_{z1}\log(\mathrm{P}_{it}) + \alpha_{z2}\log(\mathrm{A}_{it}) + \alpha_{z3}\mathrm{U}_{it} + X_{it}^{'}\beta_{z} + u_{zi}. \tag{2}$$

[1] STIRPAT model is originated from Enrich and Holdren (1971) and then reformulated by Dietz and Rosa (1994), which illustrates the impact of demographic and economic factors on the environment.