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The spatial correlation and interaction between manufacturing agglomeration and environmental pollution

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ABSTRACT

Using statistical data from 285 cities in China, this paper studies the spatial correlation and interaction between manufacturing agglomeration and environmental pollution. Using a widely used spatial correlation index, bivariate *Moran's I*, we first estimate the spatial correlation between manufacturing agglomeration and environmental pollution. We show that there is significant spatial correlation between them, and distinct patterns of local spatial concentration are identified. Then, we use a spatial simultaneous equations (SSE) model to analyze the interaction between manufacturing agglomeration and environmental pollution. We show that manufacturing agglomeration aggravates environmental pollution, while environmental pollution restrains manufacturing agglomeration. In addition, manufacturing agglomeration and environmental pollution in any one city can be affected by manufacturing agglomeration and environmental pollution in surrounding cities through spatial spillover. Finally, we put forward specific suggestions based on the conclusions for more sustainable development.

1. Introduction

There has been an increase in the formation of manufacturing agglomerations in China following the nation's rapid technological progress and economic growth. The international division system has been an especially important driver of agglomeration in Chinese manufacturing. However, with rapid industrialization and urbanization, energy supply difficulties and environmental constraints have become more and more serious. Industry's huge energy demand imposes great pressure on the energy supply and raises China's dependency on energy imports (Liu et al., 2009; Hu et al., 2014). The rapid expansion of energy consumption has also been accompanied by high pollutant emissions that have strongly polluted China's environment (Zheng et al., 2014; Qian, 2014). On the one hand, negative externalities caused by manufacturing agglomeration sharply exacerbate both pollution and energy consumption because of the high energy consumption that manufacturing requires and the high pollution that results. On the other hand, the exhaustion of energy supplies and environmental degradation conversely affect manufacturing agglomeration. It follows that manufacturing agglomeration and environmental pollution might influence each other. In this study, we use new methods in economic geography and urban economics to analyze the spatial correlation and interaction between them with a view to offering policy recommendations for environmental pollution control and a long-term sustainable plan for manufacturing development.

There is a large body of literature on the relationship between manufacturing agglomeration and environmental pollution, but conflicting findings have been reported. These can be summed up by the following three points of view. The first view is that manufacturing agglomeration aggravates environmental pollution due to the following reasons. First, manufacturing agglomeration can expand production capacity and increase energy consumption, but this may at the same time be accompanied by a sharp increase in pollutant emissions which directly leads to environmental degradation (Virkanen, 1998; Frank, 2001; Verhoef and Nijkamp, 2002). Second, the process of agglomeration itself attracts international firms and capital to "pollution havens", areas with relatively low standards of environmental regulation and higher levels of pollutants. When competing areas race to the bottom in environmental standards to attract investment, pollution is aggravated (Markusen and Venables, 1999; List and Catherine, 2000). Finally, many enterprises clustering in particular areas may exhibit "free rider" behavior, with enterprises not willing to make efforts to improve the environment and thus leading to an aggravation of environmental pollution.

The second view argues that manufacturing agglomeration is conducive to abating environmental pollution, and the main reasons are as follows. First, the scale effect of manufacturing

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agglomeration can increase residential income and fiscal revenue through improved regional labor productivity. Residents in manufacturing agglomeration regions may have more strict environmental requirements in their local areas, thereby forcing the government to adopt more stringent environmental regulations and invest more in environmental pollution control (Jie, 2006). Second, the knowledge and technology spillover resulting from manufacturing agglomerations can promote technological progress. This may stimulate enterprises in agglomeration regions to adopt more advanced, environmentally friendly production technologies which can effectively reduce pollutant emissions (Baomin et al., 2012). Finally, many enterprises clustering in a particular area can facilitate centralized treatment of pollutants. In addition, it is more convenient to recycle pollutants and achieve a circular economy when upstream and downstream industries are geographically clustered.

The third view argues that there is an uncertain relationship between manufacturing agglomeration and environmental pollution for the following reasons. On the one hand, manufacturing agglomeration affects environmental pollution not only through agglomeration effects but also through congestion effects and many other mechanisms (He and Wang, 2012). On the other hand, there are many intermediate variables in the process of interaction between agglomeration and pollution, such as city size, industrial scale, technology level, market level, and environmental regulation (Zeng and Zhao, 2009; Canfei et al., 2014). Therefore, the effect of agglomeration on environmental pollution varies under different conditions. Whether agglomeration aggravates or abates environmental pollution will depend on the aggregate response of many positive and negative effects.

Although there have been many studies on the relationship between manufacturing agglomeration and environmental pollution, previous studies have had deficiencies. The deficiencies can be categorized into three main areas, and this study aims to contribute to the existing literature in those three aspects. First, previous studies nearly always analyze the effects of agglomeration on environmental pollution but ignore the reverse effects of environmental pollution on agglomeration. In reality, agglomeration and pollution both affect each other. Agglomeration affects the environment through scale effects, competition effects, knowledge and technology spillover effects and congestion effects (Brulhart and Sbergami, 2009; Drucker and Feser, 2012), and environmental pollution or degradation can conversely affect manufacturing agglomeration. When environmental pollution is more serious, the extent of agglomeration crucially depends on the damages caused by local pollution (Lange and Quaas, 2007). Environmental regulations made by the government can also affect agglomeration (Zeng and Zhao, 2009; Kheder and Zugravu, 2012; Kahn and Mansur, 2013), and even marginal changes in environmental policy can induce discernible changes in firm location patterns (Rauscher, 2009; Kyriakopoulou and Xepapadeas, 2013). Therefore, agglomeration and pollution are both jointly determined and simultaneous; estimating the relationship using only a single polynomial equation probably produces biased and inconsistent estimates (Kelejian and Prucha, 2004; Junyi, 2006). Considering this, it is more appropriate to use a simultaneous equations model for the estimation.

Second, previous studies have always performed regression analysis on an ordinary panel or a dynamic panel, ignoring the spatial correlation and spatial spillover effects of agglomeration and pollution. In reality, the flow of contaminated water, the diffusion of air pollution, and the spread of dust all lead to spatial correlation and spatial dependence of regional environmental pollution levels (Wang et al., 2013; Qian, 2014). The clustering of many manufacturing enterprises in a particular area also has spatial spillover effects. Therefore, when estimating the relationship between agglomeration and pollution, it has been difficult for previous studies to reflect spatial evolution mechanisms because they have lacked spatial perspective and have failed to cover the spatial spillover effect. To account for this, in this study we not only incorporate geographic distance into the model but also fully consider the spatial spillover effects of agglomeration and pollution.

Third, most studies in the current literature are based on data at the provincial level (Li and Zhang, 2011; Liu et al., 2014; Zheng et al., 2014) and few studies have used urban data for analysis. It is impossible, however, to satisfy the analysis requirements using only provincial-level data. For one thing, due to the differences in the levels of industrialization and urbanization, each city has significant differences in the degree of agglomeration and pollution. It follows that using only provincial-level data may produce biased estimates and erroneous analyses because the differences between cities are being ignored (Qian, 2014). Additionally, it is difficult to fully capture the spatial spillover effect because Chinese provinces have large areas and their internal differences are significant. In this study, we use a large dataset that includes pollution data for 285 cities in China. We believe that fine-scale data provide a more accurate account of the spatial patterns and relationship between agglomeration and pollution.

Overall, the objectives of this paper are thus to systematically explore the spatial correlation and interaction between manufacturing agglomeration and environmental pollution. The rest of this paper is organized as follows. The next section introduces the model specification and description of variables. Section 3 analyzes the spatial autocorrelation. We use the spatial correlation index, bivariate *Moran's I*, to reveal the geographic patterns. Section 4 describes empirical results and discussion. We use the spatial simultaneous equations (SSE) model to investigate the interaction. The last section concludes the paper with a brief summary of findings and discussion of policy implications.

2. Model specification and variables description

2.1. Model specification

Ecologists have long been aware of spatial autocorrelation and spatial heterogeneity in their statistical data (Legendre, 1993; Anselin and Bera, 1998). Spatial autocorrelation refers to correlation of values of one variable or two variables across geographic space, and spatial heterogeneity refers to variations in relationships that are caused by the absolute location of observations (Qian, 2014; Sun et al., 2015). Spatial autocorrelation and spatial heterogeneity have been shown several times to influence both the coefficients of regressions and the inferences made during statistical analyses (Tognelli and Kelt, 2004; Dormann, 2007; Wang et al., 2013). Therefore, before using regression to build econometric models, we often conduct spatial correlation analysis, using *Moran's I* and Anselin's LISA (a local Moran indicator of spatial association), to test whether spatial autocorrelation and spatial heterogeneity exist in the data. If there are spatial autocorrelation and spatial heterogeneity in the data, traditional econometric models might be biased because they ignore such spatial factors. Therefore, spatial econometric models have become popular in the last decade because they can address spatial autocorrelation and spatial heterogeneity.

However, traditional spatial econometric models, such as spatial lag models (SLM) and spatial error models (SEM), can only address a single polynomial equation where there is no feedback effect between the explanatory and the explained variables. This study uses the spatial simultaneous equations (SSE) model to analyze the interaction between manufacturing agglomeration and environmental pollution. SSE model differs from traditional panel models in that it not only considers the spatial autocorrelation