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Air pollution and urban structure linkages: Evidence from European cities

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ABSTRACT

This paper investigates the relationship between local air pollution and urban structure with an emphasis on urban fragmentation. Using a unique dataset of 249 Large Urban Zones (LUZ) across Europe, a Bayesian Model Averaging model selection method is employed to identify the determinants of within-LUZ concentration of three air pollutants: NO_2, PM_{10} and SO_2. These are supplemented by several indices of land cover and a set of data on various economic, demographic and meteorological variables that might explain the variation of air pollution. The results of this econometric analysis support the hypothesis that urban structure has significant effects on pollution concentration. In particular, the results suggest that fragmented and highly constructed cities experience higher concentrations of NO_2 and PM_{10} and that densely populated cities suffer from higher SO_2 concentration. The findings suggest that policies favoring continuous urban areas may result in environmental improvements.

Contents

1. Introduction

Adverse effects of air pollution have been extensively documented. Annually, approximately 3.7 million people die prematurely due to outdoor air pollution worldwide [1]. Moreover, air pollution contributes to respiratory, cardiovascular diseases and lung cancer [2–5]. This incidence on health induces considerable economic impacts, manifested through increases in medical costs, number of deaths as well as the reduction of productivity through lost working days. Moreover, air pollution damages materials and buildings, but more importantly it has a clear environmental impact, e.g. Nitrogen

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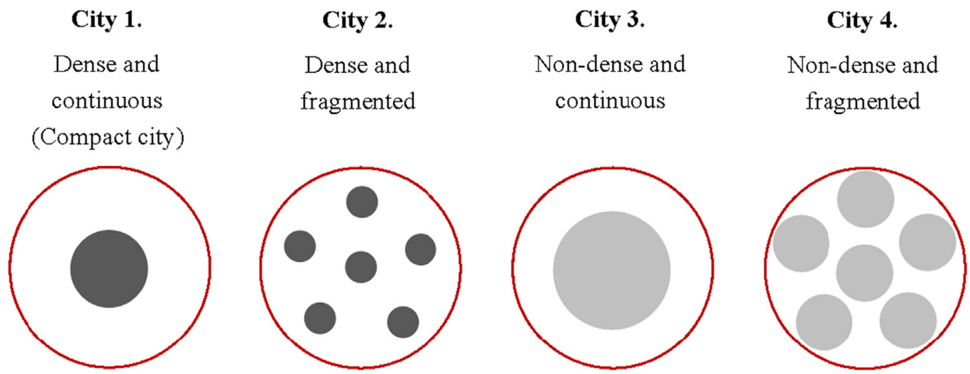

Fig. 1. Density and Fragmentation – Four city patterns, *Note*: Cities with different population densities (the darker, the denser) and different levels of fragmentation.

Oxides, Sulfur Dioxide and Ammonia contribute to the acidification of soil, lakes and rivers, causing the loss of animal and plant life and crop yields [6,7]. Therefore, understanding the factors influencing pollution concentration is essential.

Air pollution is released from various processes (e.g. industrial production and road transportation) which are driven by different socio-economic phenomena such as consumption decisions, transportation mode choices and housing and working location choices. In this context, the structure of urban areas can have strong influence on pollution emissions, this is particularly evident for transport-related pollutants. For instance, fragmented development may translate into car-dependent urban areas, and thus, worsen air quality. Better knowledge of the relationship between urban characteristics and air pollution may help to improve air quality through better spatial planning and transport policies.

Using a sample of 249 European Large Urban Zones (LUZ)[1], this paper explores the relationship between urban indicators and the concentration of three air pollutants: Nitrogen Dioxide (NO_2), Sulfur Dioxide (SO_2) and Particulate Matter (PM_{10}). While the study mainly focusses on the relationship between urban area fragmentation and pollution concentration, insights are also provided into the relationship between population density and the concentration of specific pollutants. We also test the inclusion of various land cover indicators in our econometric model, namely: the shares of artificial, agricultural, forest and wetland areas. Our approach is therefore heuristic, i.e. testing competing hypotheses of the impact of various city characteristics on air pollution. Similarly, other variables related to population, meteorological conditions, transport and economic sector composition are also tested. This approach aims to develop different models for each pollutant in order to take into account differences in pollutants' determinants. This is achieved by employing the Bayesian Model Averaging (BMA) model selection method.

Overall, the impact of economic, socio-demographic and land cover variables have different effects across pollutants; this supports the insight that different specifications need to be used for different pollutants. First, our findings suggest that urban fragmentation is positively correlated with PM_{10} and NO_2 concentration, which both result largely from transportation activity. Second, higher population density is found to be associated with higher SO_2 concentration. Overall, the findings of the study suggest that the expansion of urban areas in Europe should aim at increasing continuity and reducing population density to avoid further air quality degradation (as measured by PM_{10}, NO_2 and SO_2 concentrations). Finally, the results of this analysis show a negative correlation between GDP per capita and the level of concentration of PM_{10} and SO_2.

The remainder of this paper is structured as follows. Section 2 presents a short literature review on the linkages between air pollution and urban characteristics. Section 3 is dedicated to the empirical model and the estimation approach undertaken. Section 4 presents the data used along with some methodological aspects. Section 5 details the results while the final section concludes and draws implications for urban planning and environmental policy.

2. Related literature

Recent literature on city shape and its impacts on the environment discusses the concept of compact cities. As defined by the OECD, a compact city pattern encompasses the following features: (i) dense and proximate development patterns, (ii) urban area linked by public transport; (iii) accessibility to local services and jobs [8]. Fig. 1 illustrates different patterns of city development. Compact city pattern corresponds to City 1. The ongoing debate around the environmental benefits of compact urban areas comes partly from the fact that the notion of compactness covers various dimensions and the conclusions may diverge according to the studied urban structure indicator, air pollutant, and measure of pollution (i.e. concentration or emission levels).

Concerning fragmentation, non-fragmented urban areas (e.g. City 1 and City 3, Fig. 1) enhance connectivity, reduce mobility needs and car dependency, and facilitate the use of non-motorised transport modes, such as biking and walking. In addition to environmental improvements, continuous cities may induce benefits such as energy savings, reduction of costs of maintenance for energy and transport systems, improvement of quality of life through local services and jobs, and more efficient infrastructure investments [8]. In this respect, a compact city, given its proximate development, is expected to produce lower emissions of transport-related pollutants compared to a fragmented city (e.g. City 2 and City 4 Fig. 1).

In turn, dense development, in terms of population and buildings (e.g. City 1 and City 2 Fig. 1) may have various effects on air quality. On the one hand, dense cities may have limited need for roads and may, thus, translate into more efficient infrastructure and better public transport leading to a decrease in overall emissions per capita [9]. They also require less land and consequently have less adverse effects on biodiversity

[1] A LUZ is defined by the Urban Audit (Eurostat project) as the administrative city plus the surrounding municipalities whose at least 10% of inhabitants work in the city. This threshold ranges between 10% and 20% according to regional and national characteristics.