The General Equilibrium Effects of Urban Air Quality Policies : Application to the Grand Paris LEZ.

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1 Introduction

Urban air pollution presents complex challenges with significant repercussions on health, the economy, and society. Previous research has highlighted its negative impacts, but its relation to intra-city or intra-regional spatial structure remains an understudied area. More specifically, we want to study how policies targeting air quality can have significant effects on the distribution of population and economic activity across space and how these relocation effects can, in turn, affect their effectiveness. We focus on transport-related pollution and its relation to location choices and commuting patterns. This calls for a comprehensive approach that addresses the spatial patterns of urban development, the determinants of car use in urban settings, and the spatial distribution of pollutant emission and its transport.

The emerging urban economics literature addressing the problem of urban air pollution has for the most part tackled pollution through the lens of population density, treating it as an endogenous disamenity, acting as a congestion force, and ignoring the endogeneity of the spatial distribution of pollutant emissions and the phenomenon of atmospheric dispersion. In this paper, we build, on one side, on the literature that evaluates the impacts of transportation policies or other shocks on commuting costs in quantitative urban models (Monte et al. (2015, 2023), Baum-Snow (2020), Severen (2021)). However, the link between bilateral commuting choices, travel mode choice, and the location and intensity of emissions is yet understudied in the field. Travel mode choice models and transportation equilibrium models have also been used to study the economic and environmental outcomes associated with transportation policies, but oftentimes residents and their jobs are considered immobile (see, for instance, in the Paris case: Leroutier and Quirion (2022, 2023), Bou Sleiman (2022), Durrmeyer and Martinez (2022)). However, the ease of commute between locations is a major determinant of location choices. Some papers have brought these two aspects together (Barwick et al. (2021), Fajgelbaum et al. (2023)) but

with low attention to environmental aspects, with the exception of Borck (2019) which studies the effect of public transport policies on the aggregate level of emissions.

In this paper, we propose a novel equilibrium model that extends standard spatial equilibrium models in regional and urban economics to include the local and endogenous nature of emissions and the dynamics of pollutant dispersion and transport. Our framework also features a travel mode choice model, making it suitable for evaluating air quality policies aimed at reducing air pollution emissions and/or exposure by targeting transportation infrastructures or costs. We then calibrate the model to the Ile-de-France region and use it to assess the impacts of the Grand Paris Metropolis Low Emission Zone (LEZ) regulation on the intensity and spatial distribution of transport-related emissions, on local exposure to pollution and on the region's spatial structure. LEZs are a common traffic reduction strategy in dense urban areas, controlling the entry of highly polluting vehicles. The Paris area is used here as a case study of such a policy in a strongly monocentric setting, with a well-developed public transport network throughout the agglomeration. The LEZ area is the home of 47% of the active population of the region and hosts the work place of 62% of the population.
Particular attention is paid to the heterogeneous impacts of the policy across space. We also evaluate the effect of taking into account general equilibrium effects on welfare and pollution outcomes, compared to considering fixed location choices.

2 Methods

We develop a unified equilibrium framework in which commuting patterns, choice of travel mode, and pollution are endogenous and interdependent. Agents choose where to work and live to maximize their utility, by consuming goods and residential surface, electing their preferred travel mode, and valuing air quality. Nitrogen oxides (NO_x) pollution comes from car commuting and, to a lesser extent, from residential and business heating. Pollution dispersion is described through an advection-diffusion partial differential equation, which can account for meteorological effects such as atmospheric dispersion, transport by wind and lessivage. The source terms of this equation depends on where people choose to live and work and how they choose to commute.

We estimate a classic travel mode choice model in the spirit of McFadden (1974) using a regional transport survey carried out in Ile-de-France before the LEZ project (Enquête Générale Transport 2010-2011) to measure the importance of travel cost and duration in the commuting utility associated with each pair of municipalities. We then estimate the parameters of the location choice model in two steps as in Monte et al. (2015) using the commuting flows by city pairs of the actively employed population, as described by the French annual declaration of social data (DADS). We also recover bilateral amenity values and local productivity factors.
We use the stationary solution of the three-dimensional advection-diffusion partial differential equation with instantaneous point sources to describe long-term concentrations. We calibrate the emission factors, diffusion and decay parameters, and a smooth background concentration map to match observed annual average concentrations. We distribute road traffic emissions across space according to commuting flows and travel itineraries on the road network, recovered with a shortest-path routing algorithm.
Using our calibrated parameters and standard assumptions from the literature, we solve

the model and compute counterfactual equilibriums with an iterative algorithm. We view our solution as a long-term equilibrium, and, in this spirit, we implement a final-phase LEZ as a strict obligation to use an electric vehicle if one wants to live or work within its catchment and commute by car. We consider electric cars to be more expensive than thermic cars and to emit zero pollution. In an extension of the paper, we consider a less restrictive implementation of the LEZ based on European emission standards (traffic ban for vehicles in categories Euro 1 to Euro 4).

3 Results & Discussion

We find that the implementation of the Grand Paris LEZ is particularly effective in reducing NO_x pollution in the region (-5% on average in ambient concentrations and -25% in the average exposure level), which is unsurprising considering our restrictive definition of the LEZ. The number of car commuters is divided by 10 and the total car traffic emissions drop by 75% despite a 6 km increase in the average work-home distance, reflecting the relocation effects at stake. Our results show an influx of residents within the LEZ and particularly in the Paris city (up to +30%), which concentrates residential and productive amenities and is no longer the most polluted place in the region (now it is around the boundaries of the LEZ outlined by the A86 highway, also called Paris super-ring road, which is exempt from the restrictions). The population of distant cities also grows while it is the cities that are right outside of the LEZ up to about 35km from Paris center that loose inhabitants. However, this area enjoys significant positive spillovers in terms of pollution, because of lower population and job density, but mostly because of the drop in the number of concentric commutes driving through it towards Paris and its surroundings. The distribution of jobs follows a symmetrically opposite evolution to that of population, with the number of jobs declining within the LEZ, although with lower magnitudes. This supports the observation that the centralizing forces at stake in the region seem to hold more strongly in the labor market than in the residential market.

We find that the LEZ implementation decreases aggregate welfare by 13%, while a more "naive" approach, considering only travel mode switch without relocations, concludes to a positive 1% welfare benefit. This is of course reliant on our assumption on the disamenity that pollution represents, which we vary in robustness tests. It also overestimates environmental gains but only very slightly. This discrepancy is due to ignoring the draw toward the center induced by higher commuting costs and lower ambient pollution, hence the larger the exposed population and the feedback effects on rents and wages (note that we do not account for congestion effects).
Finally, we test, in counterfactual exercises, whether other parts of the region transportation policy plan (e.g. fare dezoning of public transport, creation of new lines) are well-suited to alleviate the costs and structural changes induced by the LEZ.

4 Conclusion

This paper proposes a novel theoretical framework for studying the general equilibrium effects of air pollution control policies in urban environments. It contributes to the growing literature on the indirect effects of air pollution, air quality policies, and transportation policies in urban areas. It suggests that LEZs and other air pollution policies can have

significant effects on the distribution of population and economic activity throughout a whole region, which affects their effectiveness. In addition, we show that omitting these general equilibrium effects can lead to wrong perceptions about the impacts of such policies.

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