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Urban spatial structure, suburbanization and transportation in Barcelona ☆

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A B S T R A C T

I investigate the effect of improvements to the transportation infrastructure on changes in location patterns of population in Barcelona, Spain between 1991 and 2006. At a census tract level, I verify and extend the finding of Baum-Snow (2007a) that transportation improvements cause suburbanization: (1) improvements to the highway and railroad systems foster population growth in suburban areas; (2) the transit system also affects the location of population inside the central business district (CBD). To estimate the causal relationship between the growth of population (density) and transportation improvements, I rely on an instrumental variables estimation that uses distances to the nearest Roman road, the nearest 19th century main road, and the nearest 19th century railroad network as instruments for the 1991–2001 changes in distance to the nearest highway ramp and the distance to the nearest railroad station.

1. Introduction

I investigate the effects of highway and railroad improvements on changes in urban spatial structure that occurred in the Barcelona Metropolitan Region (BMR) between 1991 and 2006. I find that improvements to the transportation infrastructure cause BMR suburbanization and influence its spatial pattern by attracting population to non-central suburban tracts that in 1991–2001 had improved access to the highway system and to central and non-central suburban tracts near railroad stations. Besides causing suburbanization, transportation also affects residential location decisions in the CBD by attracting population near railroad stations. Overall, these results confirm that transportation infrastructure and its improvements are important elements needed to explain urban spatial structure in general and the process and spatial pattern of suburbanization in particular.

This investigation is of interest for three reasons. First, it furthers our understanding of the role of transportation infrastructure in shaping cities. Baum-Snow (2007a) shows that transportation improvements cause suburbanization. At a census tract level and for different city areas, my results confirm this finding and indicate that improvements to the transportation infrastructure also influence the spatial pattern of suburbanization. Since suburbanization leads to greater resource consumption and CO_2 emissions (Kahn, 2000), and to an inefficient supply of public services (Bertaud, 2002), the findings reported here provide a basis for analyzing potential policy interventions that seek to redirect the spatial pattern of suburbanization and mitigate its negative consequences.

Second, these new results are also useful for urban planners in two additional ways. Since improvements in transportation infrastructure cause changes in population location patterns, planning policies should also consider the complementary changes in the spatial distribution of the demand for public services. Furthermore, since the effect of transportation improvements depends on the city area where infrastructure is located, planning policies should be spatially differentiated.

Finally, this research is important because it is centered on a European city and thus permits comparison with previous studies of US cities. Despite differences in city population size and density, land-use planning, or the use of public transit between US and European cities, these results show that suburbanization is an ongoing phenomenon in a big European city and that it is also related to the transportation infrastructure.

The empirical strategy that I develop below is based on estimating the relationship between the growth of population (density) in

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a census tract and its transportation improvements. Such improvements include the changes in census tract distance to the nearest highway ramp and the census tract distance to the nearest railroad station. Departing from this unconditional relationship, I gradually control for the initial level of population density, proximity to the main centers, geography, and history (past populations). I implement this strategy for three different city areas: CBD, subcenters and non-central suburban areas.

To carefully establish this causal relationship, I consider an important identification problem: the simultaneous determination of population growth and transportation improvements. Planners may wish to serve areas expected to have strong population growth or, alternatively, they may choose to serve areas expected to have weak growth. In both cases, reverse causation would be at work. To solve the identification problem I use instruments as sources of exogenous variation for transportation improvements.

Based on the history of the infrastructure development in Barcelona (and in Spain more broadly), I derive three instruments from maps of the Roman roads, main roads constructed before the end of the 19th century, and the railroad lines built during this same time period. These old infrastructures were not placed randomly throughout the landscape. On the contrary, their supply and location was influenced by the size of contemporary populations and the suitability of geography for building these infrastructures. Moreover, these factors may have also influenced modern transportation improvements. Thus the abovementioned variables of geography and history (past populations) are required in order to guarantee the exogeneity of these instruments.

This research contributes to the existing literature in two ways. First, it extends the conclusions of Baum-Snow (2007a) who investigated the effect of the interstate highway system on suburbanization and found that highway improvements contribute to central city population decline. Using data on a much finer geographic scale, I also investigate the effect of transportation improvements inside the central city and the suburbs (suburban subcenters and non-central suburban areas). I also distinguish between the effects of the highway system and the railroad network. Results reported here thus suggest that transportation improvements influence the suburbanization process by attracting population near railroad stations and to non-central suburban areas that improve access to the highway system.

The present work is also related to the large literature on urban spatial structure. Despite the central role of transportation infrastructure in theoretical models of urban spatial structure, much of the empirical literature is concerned with its effect on the spatial distribution of land prices. Only a small number of papers study the relationship between transportation and the spatial distribution of population and employment.[1] With the exception of Baum-Snow (2007a), previous work has not considered the simultaneous determination of population density (growth) and transportation infrastructure (improvements). As mentioned above, I resolve this endogeneity problem by exploiting the exogenous variation in three instrumental variables.

The remainder of the paper is structured as follows. In the next section, I propose an empirical strategy for estimating the effects of transportation infrastructure improvements on population (density) growth. In Section 3, I describe transportation infrastructure of Barcelona and I then present the main results in Section 4. Finally I present conclusions in Section 5.

[1] Steen (1986), Baum-Snow (2007a), and Garcia-López (2010) estimate the effect of transportation infrastructure on population density patterns, and McMillen and McDonald (1998) on employment density patterns. Boarnet (1994a,b) and Bollinger and Ihlanfeldt (1997, 2003) consider transportation infrastructure (improvements) as a possible determinant of intrametropolitan population and employment growth.

2. Urban spatial structure and transportation: theory and estimation

The classical monocentric land use theory developed by Alonso (1964), Mills (1967) and Muth (1969) (AMM) considers a non-limited, radial-type transportation infrastructure covering the whole city in the same way and therefore allowing the same access to the unique main center or CBD from any point located at the same distance from this CBD. The AMM way of modeling transportation infrastructure leads to a homogeneous reduction in population density as population moves away from the CBD (the CBD gradient), but not as population moves away from transportation infrastructure. When improvements in transportation infrastructure increase transport speed, population density decreases near the CBD and increases in the suburbs and, as a result, the CBD gradient flattens (Wheaton, 1974).[2]

To motivate my econometric strategy, the works by Anas and Moses (1979) and Baum-Snow (2007b) are more useful because they deal with transportation infrastructure in a more realistic way. Anas and Moses (1979) extend the AMM model by considering two competing transportation infrastructures. First, the classical AMM-transportation infrastructure based on a dense network of radial streets. Second, a high speed transit system based on sparse radial corridors. Depending on the cost of alternative transportation modes, the authors show that both rents and population densities might decrease with distance to the transit lines (a transportation infrastructure gradient).

More recently, Baum-Snow (2007b) incorporates highways into the transportation infrastructure of a monocentric city. Population commutes to the CBD using these faster sparse radial highways or using a dense network of streets that connects each point in the city to the CBD and to the nearest highway.[3] Concerned with the suburbanization process and the impact of highway improvements previously documented in Baum-Snow (2007a), the author shows that new highways affect urban spatial structure by causing population to spread out along the highways and, as a result, by increasing population densities in areas near highways and decreasing elsewhere.

Based on these works and following other empirical studies, the effect of transportation infrastructure on urban spatial structure can be examined by estimating a type of population density function[4]:

$$lnD_{it} = A_0 + \gamma_{inf} d_{inf,it} + A_1 X_{it} + \epsilon_{it} \quad (1)$$

where lnD_{it} is the natural logarithm of population density for census tract i in year t and $d_{inf,it}$ is the distance from the tract centroid to the transportation infrastructure. γ_{inf} is the transportation infrastructure gradient and measures whether population density increases or decreases with distance to this infrastructure. X denotes a vector of observed census tract characteristics such as location, geography, and history. ϵ is the error term.

To study whether transportation improvements affect changes in urban spatial structure, I estimate a first-difference specification based on Eq. (1):

[2] Non-monocentric/polycentric models allow the possibility of several main centers (Fujita and Ogawa, 1982; Anas and Kim, 1996; Lucas and Rossi-Hansberg, 2002). Since they adapt the AMM-type transportation infrastructure, the resulting spatial distribution of population only follows a decreasing density pattern from the CBD (the CBD gradient) and from the subcenters (subcenters' gradients).

[3] Baum-Snow (2007b) also extends Anas and Moses (1979) by allowing for different ''technologies'' to access the highways from the streets.

[4] This functional form is the linearized version of a negative exponential function derived from a quasilinear utility (Baum-Snow, 2007a). Monocentric density functions only include the distance to the CBD as explanatory variable (Clark, 1951; McDonald, 1989). Polycentric studies also consider the distance to the nearest subcenter (Anas et al., 1998).