Spatial panel models to examine travel demand: A case study of Randstad, the Netherlands

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KEYWORDS

Daily travel distance, land use, policy, panel, spatial interaction, Randstad

INTRODUCTION

A host of factors including socio-economic, land use, transport infrastructure, and policy characteristics determine the demand for travel in a region. Changes in travel demand in response to these factors are gradual and unobservable at the cross-section level, as people's travel behaviour evolves over time gradually. Furthermore, travel demand and traffic flow in a certain area are likely to be dependent on concurrent and previous travel demand in neighboring areas, as well as the transport infrastructure, land use and policy characteristics of the neighboring areas. For instance, investments in highway infrastructure in a municipality can lead to increases in car travel in neighboring municipalities in subsequent years. Thus, travel demand should be investigated i) in relation to a comprehensive set of factors (including transport infrastructure, land use, socio-economic and policy variables), ii) in the long term ii) at the regional scale iii) while controlling for temporal and spatial interactions. However, the existing literature on travel demand and its determinants overlook one or several of the above criteria.

This study addresses the above gaps by investigating average daily kilometres travelled as a measure of travel demand in the polycentric Randstad region in the Netherlands. It applies spatial panel models (Elhorst, 2014) to investigate developments in average daily kilometres travelled and its determinants for 143 municipalities from 1980 to 2010. Furthermore, it distinguishes between kilometres travelled by three modes, namely, car, train and bicycle at the municipal level.

DATA

Various sources were used to create a long-term geo-referenced database. We derived average daily kilometers travelled by car, train and bicycle from the Dutch National Travel Surveys, which have been conducted annually since 1979. Adult respondents living in the Randstad who had reported at least one trip by car, train or bicycle were extracted. Respondents from a number of consecutive years were merged to make sample sizes comparable for seven time points: 1980, 1985, 1990, 1995, 2000, 2005 and 2010. The sample size at each time point ranges between 10,000 and 35,000 respondents. The data were then aggregated at the municipal level, the smallest spatial level where all the data were consistently available over three decades. Land use, accessibility, socio-economic, policy and travel behaviour data with varying measurements were recoded and adjusted for municipal boundary changes to generate a consistent dataset for the seven time points. The measurements of 143 municipalities over the seven intervals resulted in a panel dataset with 1001 observations. Figure 1 presents the average daily kilometers travelled by car, train and bicycle for different types of municipalities in the Randstad region and highlights how travel demand varies by year and the location of municipalities. It is evident from Figure 1 that urban municipalities are linked to higher train and bicycle kilometre travelled while rural municipalities correlate with higher car kilometres. Furthermore, a decreasing trend, especially in the second half of the 2000s is visible in the kilometres travelled by car and train as opposed to rising bicycle kilometres travelled in this period.

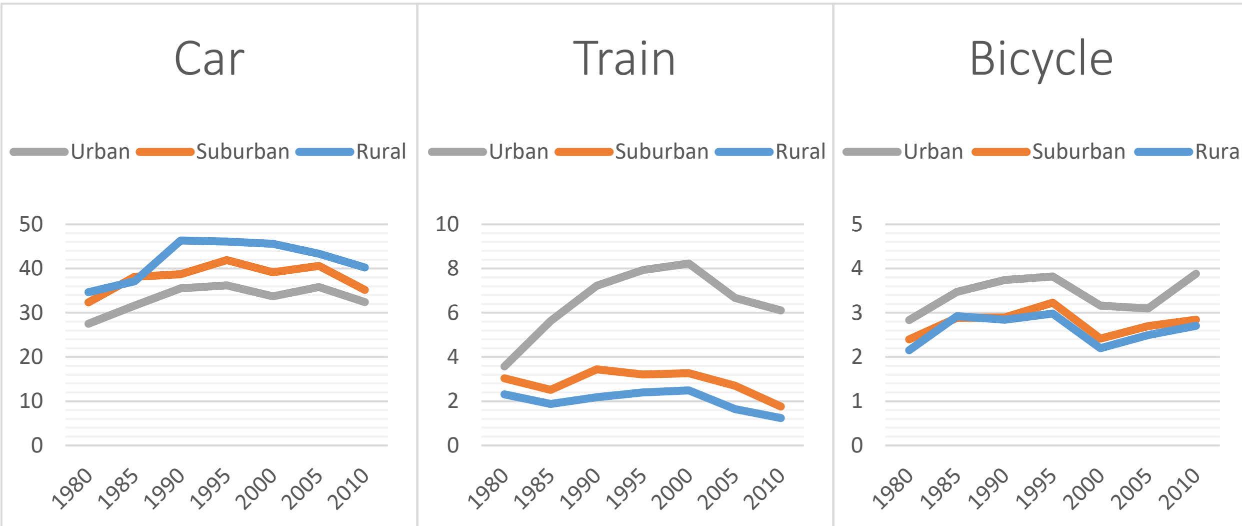

Figure 1. Average daily distances travelled by car, train and bicycle between 1980 to 2010 [km]

METHODOLOGY

We hypothesized that travel demand in municipality q at time t is affected by:

- Influential factors such as land use, accessibility, socio-demographic and policy characteristics in municipality q
- Influential factors from surrounding municipalities in the current and past time periods – to capture the lagged spatial influence of independent variables
- Travel demand in surrounding municipalities in the current and past time periods – to capture the lagged spatial influence of the dependent variable

The above hypotheses were tested using spatial panel models estimated using maximum likelihood approach. The general specification of these models can be written as:

$$y_{qt} = X_{qt}\beta + \delta \sum_{j=1}^{Q} W_{qj} y_{jt} + \sum_{j=1}^{Q} W_{qj} X_{jt}\gamma + \rho \sum_{j=1}^{Q} W_{qj}\varphi_{jt} + \mu_q + \epsilon_{qt}$$

Where:

- y_{qt} is the average daily distance travelled by each mode as dependent variables.
- X_{qt} is a the vector of attributes at municipality q and time t with its corresponding coefficient β.
- W_{qj} is an element from a spatial weight matrix W. The spatial weight matrix W defines the spatial arrangement of the municipalities or in other words the neighbouring areas.

Here, W is based on the inverse of distance (and other functional forms such as squared distance) between municipalities. The diagonal of W matrix is set to be zero to prevent the use of y_{qt} to model itself.

- δ is the spatial autoregressive coefficient, which accounts for observed effect of surrounding municipalities' demand on the dependent variable, γ is similar to β but accounts for spatially lagged impact of independent variables (spatial spillover effect), φ_{qt} represents the spatial autocorrelated error term and ρ reflects the spatial autocorrelation coefficient.
- μ_q represents a spatial specific effect to account for all the municipality-specific time-invariant unobserved attributes. It is treated as random term that is independently and identically distributed with zero mean and variance ${\sigma_\mu}^2$.
- ϵ_{qt}, is the random error term, assumed to be an independently and identically distributed normal error term for q and t with zero mean and variance σ^2.
- To simplify the model notation, temporally lagged variables are considered within X_{qt}, y_{jt}, and X_{jt}.

RESULTS

Model results indicated the presence of spatial autocorrelation. More importantly, they confirmed the significance of spatial lags for both the independent and dependent variables. In other words, travel demand in a certain municipality is influenced by both: i) the travel demand in its surrounding municipalities, as well as ii) the influential factors in the surrounding municipalities. Significant factors positively related to average daily train kilometres travelled were the population density of the built up area [persons/sq. km] and the density of railway lines [km/sq. km] among others. Interestingly, these variables were also significant but negatively related to car kilometres travelled. Further, the municipalities with higher population density of built up area and lower car availability for households were more likely to experience higher bicycle demand as indicated by positive and negative coefficients of respective variables. Finally, policy indicators were also found to be significant: The municipalities within the green and preserved rural area of the so-called Green Heart were associated with lower train kilometres travelled. The presence of Vinex neighbourhoods –which were planned in mid 1990s adjacent to existing cities, and are criticised for their lack of connection to public transport– were shown to correlate with higher car kilometres travelled.

References

Elhorst, J.P., 2014. Spatial Panel Data Models. Springer, Berlin, Heidelberg, pp. 37–93. https://doi.org/10.1007/978-3-642-40340-8_3