



# Temporal dynamics in the relationship between land use factors and modal split in commuting: A local case study

Lorea Mendiola<sup>a,\*</sup>, Pilar González<sup>b</sup>

<sup>a</sup> The University of the Basque Country (UPV/EHU), PARTE HARTUZ Research Group, Department of Foundations of Economic Analysis II, Avda. Lehendakari Agirre, 83, 48015 Bilbao, Spain

<sup>b</sup> The University of the Basque Country (UPV/EHU), Econometrics Research Group, Department of Econometrics and Statistics & Institute for Public Economics, Avda. Lehendakari Agirre, 83, 48015 Bilbao, Spain



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## ABSTRACT

This paper analyses the relationship between land use and the modal split in commuting over time to assess, from a dynamic perspective, the effectiveness of land use policies in managing mobility. The analysis covers 2001 and 2011 at municipal level in Biscay (Spain). The methodology used is based on SUR models, which take into account the potential temporal interdependence between periods. Furthermore, spatial econometric techniques are applied to avoid biased results and unreliable inferences due to spatial dependence. The results indicate that urban density is a key factor, as it is the only factor relevant for all means of transport and time periods. It can be seen that the relationship between land use factors and modal split varies over time for commuter journeys made by private transport and cycling/walking, suggesting that there is a need to monitor the effectiveness of land use policies so as to adapt them to the characteristics of each period.

## 1. Introduction

Impacts associated with motorised urban mobility have grown into major environmental challenges. Experience has shown that solving them requires not just improvements in the range of transportation on offer but also the managing of demand for mobility, so as to limit the need to travel and direct it towards more environmentally friendly means of transport (EC, 2004). In the last few decades numerous empirical studies have analysed the links between the characteristics of cities and their mobility patterns with a view to assessing whether the land use policies are valid for managing the demand for mobility (see Handy, 1996; Crane, 2000; Ewing and Cervero, 2010; Litman and Steele, 2017 for reviews of the relevant literature). Their findings show that land use factors such as density, urban design and functional diversity, along with the characteristics of the transport system and the specific socioeconomic profile of the population, have impacts, which are modest individually but are cumulative and synergistic, and they are relevant in explaining modal split. The magnitudes of the associations between land use variables and mobility patterns found in these studies fall into relatively stable ranges, even allowing for the variety of econometric methods used (Boarnet, 2011). Nevertheless, they examine the relationship at a single point in time, so they cannot be used to determine the temporal relationship between variables and evidence of

cause and effect cannot be assumed (TRB, 2009). There is no reason to expect the influence of land use factors on mobility patterns to be stable either across geographies or over time. To analyse whether this relationship varies over time and whether a shift in urban development can lead to a change in commuting behaviour in a dynamic perspective a longitudinal approach is needed, with data from various time periods. Such an analysis would further the understanding of the relationship between land use factors and mobility and help compare the effectiveness of different land use policy strategies.

Major barriers to longitudinal land use-mobility studies are the difficulty of collecting multi-year travel information and the fact that substantial land use change often occurs over a long period. This explains why few studies have adopted this approach (TRB, 2009; Zhang and Zhang, 2016). Even so, recently there have been attempts to apply a longitudinal design to these relationships, using different methodologies and different variables to characterise mobility. Among the relevant studies, mention should be made of Trivisi et al. (2010), who compare trends in the impact of mobility in two different periods using descriptive statistics; Horner and Schleith (2012), who analyse jobs and housing locations using theoretical minimum and maximum commutes based on a linear optimisation model; Zegras and Hannan (2012) and Guerra (2014), who use logit and tobit models to study car ownership and car use, respectively; Bai (2013) and Zhang and Zhang (2016), who

\* Corresponding author. Present address: Faculty of Economics and Business Studies, University of the Basque Country (UPV/EHU), Avda. Lehendakari Agirre, 83, 48015 Bilbao, Spain.  
E-mail addresses: [lorea.mendiola@ehu.es](mailto:lorea.mendiola@ehu.es) (L. Mendiola), [mariapilar.gonzalez@ehu.es](mailto:mariapilar.gonzalez@ehu.es) (P. González).

focus on non-driving mobility and non-work journeys, respectively, using multilevel longitudinal logit models; and van de Coevering et al. (2016), who apply cross-lagged panel structural equation models to study modal choice defined as the amount of car use compared to other modes. Results suggest that there is a causal influence from urban development on travel behaviour (van de Coevering et al., 2016), but while some studies observe some degree of temporal stability (Horner and Schleith, 2012; Guerra, 2014), most consider that these influences change over time. These results confirm the importance of longitudinal analysis in land use-travel studies, suggesting that the short-run land use elasticity derived from static analyses may not be suitable for assessing the long-run effect of land use policies such as densification and mixed-use development for managing mobility demands (Zegras and Hannan, 2012; Bai, 2013; Zhang and Zhang, 2016).

In this paper we conduct an analysis to determine whether the relationship between land use factors arising from different types of urban development and the modal split for commuting remains stable over time using econometric models. Many of the longitudinal studies conducted under this framework (Guerra, 2014, Zegras and Hannan, 2012) suffer from the limitation that they fail to take into account the potential temporal interdependence between the different periods analysed, which leads to a loss of estimation efficiency. To deal with this problem, we propose the use of Seemingly Unrelated Regressions (SUR) models, as suggested by Zellner (1962), which consist of several regression equations, one for each period of time, and take into account temporal interdependence between periods by means of the covariance matrix of the error terms. The specification of SUR equations is based on a review of the existing literature, which concludes that the factors which influence mobility patterns are of different nature but can be classified in three main groups: land use, characteristics of transport systems and socio-economic factors (see Polzin, 2004).

The analysis is conducted at municipal level because no longitudinal data on mobility at individual level are available. Mobility data at municipal level are available from 2001 onwards, and are taken from the Spanish population and housing censuses, which are published every 10 years. The study therefore covers only the 2001 and 2011 periods. When working with geo-referenced data, as in this case, so-called “spatial effects” (heterogeneity and spatial dependence) often appear when the behaviour of a variable observed at a number of points in space is to be explained via a set of variables observed at those same points. The consequences of these effects on the validity of the inferences made in these cases cannot always be dealt with by standard econometrics. Spatial econometric techniques are applied to deal with the specific characteristics of geographical data (Anselin, 1988a) and to avoid biased results and unreliable inferences due to the tendency of geographical data to be spatially dependent. Therefore, we analyse the temporal stability of the relationship between land use factors and modal split by estimating a SUR model with spatial autocorrelation (Anselin, 1990). Such models have been used in literature in different areas of interest, such as economic analysis, health and transportation, among others (Rey and Montouri, 1999; Le Gallo and Dall’erba, 2006; Moscone et al. 2007; Wang and Kockelman, 2007; Beck et al., 2012; Lopez et al., 2014), but as far as we know they have not previously been applied to mobility-related issues.

The paper makes two main contributions: first, it conducts a longitudinal analysis of the relationship between land use factors and modal split in commuting within the framework of SUR models that allows the coefficients to vary for different years and also captures temporal interdependence between periods; and second, it applies spatial econometric techniques in this field to deal with the spatial effects that usually appear when working with geographic data.

The study area selected is Biscay, one of the three provinces that make up the Autonomous Community of the Basque Country in northern Spain. Biscay, a historical industrial and financial centre in this region, underwent from the 1970s onwards a process of deindustrialisation that culminated in the 1990s with a substantial shift in the

basis of its economy. This new economic situation radically changed its urban dynamics and brought about a process of de-urbanisation involving major internal migration from former industrial hubs to more rural areas with less public transport, leading to a significant increase in motorised mobility, particularly using private vehicles. This trend did not continue with the same force between 2001 and 2011, a period in which there was a slight recovery in urban areas after two decades of population loss. It has to be taken into account that the economic perspectives in 2011 were unlike those in 2001. At the turn of the century, Biscay was enjoying a period of economic prosperity, with strong rates of growth (about 8% in GDP and 5% for employment in 2001). This trend continued up to 2009, when the effects of the global financial crisis began to be felt in the area (between 2009 and 2011 employment fell by 6.9%). In 2011 the main macroeconomic indicators were still higher than in 2001 but the economic expectations in 2011 were no longer good. This may have adversely affected population movements linked to the de-urbanisation processes initiated in the previous decade, as such movements tend to decrease in times of crisis (Fielding, 1998), with the corresponding effects on mobility patterns. Analysing how these changes may have influenced the stability of the relationship between land use factors and modal split in commuting therefore seems to be an interesting case study.

The paper is structured as follows: Section 2 outlines the case study, describing the urban transformation that took place in the province of Biscay and the nature of the mobility patterns. Section 3 describes the variables considered in the econometric analysis and explains the dataset used and Section 4 presents the methodology applied: Seemingly Unrelated Regression models with spatial autocorrelation. The main findings of the econometric analysis are shown in Section 5 and Section 6 presents some conclusions and limitations of the study.

## 2. Case study

According to Eustat (the Basque Statistics Institute), at the end of the period studied, in 2011, Biscay had a population of 1,152,849 spread over an area of 2221 km<sup>2</sup>, divided into 111 municipalities. It is a province of great contrasts, with industrial areas, natural parks, highly-urbanised and markedly rural areas. It is the industrial and financial heart of the Basque Country. Biscay suffered a prolonged period of crisis from the late 1970s to the early 1990s that led to a switch from its traditional industrial economic base (mining, steel and metallurgy) to a more service-oriented economy. With the onset of that crisis, the structure of densely populated industrial cities began to change and the first signs of residential decentralisation and relocation of industrial activities on the periphery appeared. Jobs and homes began to move out towards more rural areas and new, low-density residential areas arose.

With respect to population movements, Fig. 1 shows that there was a sharp decline in the urban population and an increase in the rural population between 1991 and 2001, a clear example of a de-urbanisation process, which did not affect all geographical areas equally, since only municipalities with less than 10,000 inhabitants experienced positive population growth (see Table 1). Furthermore, those who moved out of former industrial city centres to smaller, more environment-friendly towns, had certain socio-economic features: they were mainly young skilled workers with children of a medium-to-high socio-economic level (Torres, 2014). This group can be expected to be associated with more frequent use of private cars.

From 2001 to 2011 the rural population can be seen to have continued to grow, but at the same time medium- and large-sized municipalities experienced a change in trend, showing positive growth. This could be interpreted as that Biscay has followed the dynamics observed during the last two decades of the 20<sup>th</sup> century in metropolitan areas in southern Europe and the United States, where big cities recovered their powers of attraction: a process known as redevelopment. This phenomenon was not, however, as evident in Spain. In cities such as

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