

The impact of accessibility changes on the local development: a spatial approach

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Abstract

Throughout the years, the European Commission has allocated significant financial resources to road infrastructure construction, based on the belief that it would boost socioeconomic development. However, literature evidence shows it is not consensual whether those investment policies will yield the expected outcomes. The main goal of this work is to shed light on where, and to what extent, accessibility changes due to road infrastructure construction might contribute to boost socioeconomic development at the municipal scale and regional cohesion, resorting to a case study consisting of the municipalities located in the Center Region of Portugal. The analysis uses spatial statistical methods and considers both space and time-lagged variables simultaneously, while controlling for endogeneity, spatial autocorrelation and demographic variables. Results show that accessibility changes induced by 20 years of road infrastructure construction had, in general, a positive impact on the development of the Center Region municipalities. However, depending on how accessibility is defined, negative impacts were also reported, as well as impacts that depend on geographic location. It is suggested that these latter impacts might be related to population migration within the Center Region. Concerning cohesion, no significant impacts of accessibility changes were found.

1. Introduction

The construction of road infrastructure implies large investments and the involvement of a vast number of institutions. An accurate evaluation of where, and to what extent, transport infrastructure might generate added value plays a paramount role in the definition of public policies. Policymakers need to consider the socio-economic impacts of transport infrastructure investments, and whether the benefits overcome the costs (Tsamboulas, 2007; Freiria et al, 2022).

Several authors have focused on understanding the impact of transport infrastructure on regional development, but despite these efforts no definitive conclusion has been reached. The point is that an increase in accessibility, due to the construction of transport infrastructure, can have either positive or negative impacts on regional development, and it remains unclear what might be the factors determining the direction of that impact. For instance, evidence exists that while new transport infrastructure can contribute to the reduction of transport costs and attract people, it can also increase the competition for factors of production and markets across and inside regions (Chandra and Thompson, 2000; Moreno and López-Bazo, 2007). An added difficulty in ascertaining the relation between the two variables is the research tendency to focus on the regional scale, a fact that has been recognized as a limitation of the current literature (Holtz-Eakin and Schwartz, 1995; Álvarez – Ayuso et al., 2016; Rokicki et al., 2021). Indeed, within each region accessibility changes can have different impacts, as shown by Gagliardi and Percoco (2017) and González-González and Nogués (2019), hinting that the issue may require a higher spatial resolution than previously thought. Accessibility itself may also require higher resolution, as authors such as Silva and Altieri (2022) realized that local accessibility may have been undermined by regional accessibility. Moreover, concerns on methodological issues have been raised by Lu et al. (2022), who pointed out that previous studies have been disregarding spatial autocorrelation of transport at the municipal level.

Regardless of the study scale and methodologies, a great deal of effort is made to evaluate the global economic impacts at an *ex-ante* phase. However, the local spatial economic inequalities that may appear at an *ex-post* phase of transport infrastructure construction are

seldom considered (Beyazit, 2015; Ferrara et al., 2017; Vickerman, 2017). There is also a need to go beyond production functions to quantify socio-economic impacts (Rosik and Wójcik, 2022) and some studies took endogeneity into account, but did not consider spatial autocorrelation and vice-versa.

This work proposes to fill some the above literature gaps by introducing an *ex-post* methodology that seeks to identify the reasons why some municipalities benefit from transport infrastructure investments while other are negatively affected. By studying the relation between transport infrastructure and regional development at the municipal (intra-region) level, the methodology deals with data at level of precision necessary to unveil effects at this scale. The approach makes use of two statistical models, namely a generalized spatial two-stage least-squares regression, which yields a global picture, considering spatial autocorrelation and mitigating statistical endogeneity, and a geographic weighted regression that can help detect effects at the local level. Throughout this article the expression “regional scale” or “regional level” will refer to administrative divisions akin to the European NUTS2 designation, whereas “local scale” or “local level” refer to divisions at municipal level.

The methodology was applied to the NUTS2 Center Region of Portugal, disaggregated at the local level (municipality), whose motorway network has grown more than 100% in the last two decades (see Figure 1). The period of analysis is comprehended between 2001 and 2021, with some adjustments related with data availability. This work intends to answer three questions:

- H1: Did the increase of road accessibility in the Center Region of Portugal in the period 2001-2021 have a significant impact on economic growth?
- H2: Were there any contrasting effects at the municipality level, i.e., did the improved road network benefit some municipalities and caused a negative impact on others?
- H3: Did the increase of accessibility in the Center Region of Portugal in the period 2001-2021 contribute to regional cohesion?

The contribution of this work to the state-of-the-art is relevant for two reasons: firstly, and complementing previous studies, this work considers spatial autocorrelation and mitigates

statistical endogeneity, two issues that should be considered when assessing the impact of accessibility on regional development. Secondly, and because of the former point, the methodology and case study provide evidence that helps understanding why some municipalities benefited from road infrastructure improvements while others were impaired by it. This understanding of the impact of transport infrastructure at the local level can then be used by decision makers to design planning strategies more suitable to the characteristics of each municipality.

2. Related work

Initial reports on the relation between transport infrastructure and regional development include Aschauer (1989) and Munnell (1992), who found a positive and statistically significant relationship between highway capital stock and productivity. Button (1998) also found a positive relationship between GDP per capita and transport infrastructure investment. However, doubts on this direct connection were cast when Holtz-Eakin and Schwartz (1995) failed to find a significant effect between public sector infrastructure and private productivity. Later on, it was found that even within the same country contradictory results were possible: in Spain, and according to Pereira and Roca-Sagalés (2003), transport infrastructure has had a positive effect on the Spanish economy, while Moreno and López-Bazo (2007) demonstrated the opposite effect, and Álvarez et al. (2016) found no evidence of any effects. Possible clarification for the contradictory results emerged when Rokicki et al. (2021) showed that accessibility can have a positive impact at the regional level, but a negative at the local level, in line with Delgado and Alvarez (2007), who also found a positive relationship between high capacity roads and economic performance in the regions where motorways were built and a negative spillover effect in other regions. Arbués et al. (2015) showed that negative effects at the local scale are not inevitable, as those authors found that road infrastructure effects can be positive overall, albeit they recognized that the effect can be stronger in the regions where new roads were built than in the remaining regions.

Thus, given that results typically vary considerably within a region, the literature evidence suggests that the relation between transport infrastructure and regional development may

depend on the dimension of the study unit. The role of spatial unit size was confirmed by Álvarez-Ayuso et al. (2016) who found, using a spatial autoregressive model with gross added value as (lagged) dependent variable, negative spillovers in the poorest regions and positive spillovers in the richest regions, whose relative magnitude increased when considering smaller spatial units. Komornicki and Spiekermann (2018) carried out an assessment of the consequences of investments in road and rail transport on spatial development in several European countries, having found a growing polarization around places with greater accessibility in Poland and, to some extent, Sweden and Finland. This shows that discrepancies need not exist in the first place: they could be induced by imbalances in transport investments. Explaining variability may also require considering more socio-economic variables. There are, however, difficulties in ascertaining what those variables might be, as Ribeiro et al. (2010) demonstrated that factors exist that have a higher impact on economic growth than accessibility. According to those authors, factors such as, e.g., the educational profile of the population can have an impact on the purchasing power that dwarfs that of road accessibility. Also, Crescenzi and Rodríguez-Pose (2012) claimed that a region's innovation capacity has a higher impact on the economy than its transport infrastructure endowment.

Another factor that may determine whether investments significantly improve economic performance is the initial state of the transport infrastructure. Studies in countries with low initial conditions, namely Latvia (Skorobogatova and Kuzmina-Merlino, 2017), Poland and Romania (Komornicki and Goliszek 2023), all show positive responses in economic performance in the wake of an inflow of EU structural funds. The same goes for investments in Uganda (Muvawala et al., 2021). Countries with denser road networks had more modest gains from transport investment (Crescenzi and Rodríguez-Pose, 2012). Indeed, a statistical study by Freiria et al. (2022) confirmed that improved accessibility may not necessarily translate to higher regional performance and suggested that complementary policies might help in synergizing the two.

Methodological issues can also lead to limitations in drawing conclusions on the transport infrastructure/regional development relation. In this respect, the first works were based on econometric methodologies such as production functions, i.e., relations between inputs and

outputs (Aschauer, 1989; Munell, 1992; Holtz-Eakin and Schwartz, 1995; Slodoba and Yao, 2008). While statistical production function models remain the main explicative mechanism, the choice of variables and methods has been evolving: Holtz-Eakin and Schwartz (1995) are among the first that considered the spatial component, namely at the state scale in the USA, for assessment of highway stock spillovers. Boarnet (1998) developed similar work applied to California's counties, adding spatial lag in the capital stocks. Moreno and López-Bazo (2007) also followed the latter idea to assess the impact of public capital stock on the economic growth of Spanish regions. Arbués et al (2015) used a spatial Durbin model including spatial lags of the independent and dependent variables to study the contribution of transport infrastructure to the gross added value in Spanish regions. Regardless of methodology, results of those authors followed the same trend as other studies: positive, negative, and neutral effects of accessibility on development were all found at both local and regional scales, as well as cases where socio-economic factors had an effect bigger than accessibility.

Summing up, the diversity of results shows that the relation between transport infrastructure and regional development is complex. Albeit some trends can be found, i.e., that some administrative divisions (typically the richer ones) tend to benefit more from transport investments than others, it remains difficult to ascertain the underlying mechanism of the relation. Brakman et al. (2021) analysed these discrepancies in the light of new economic geography models, arguing that spatial linkages between administrative divisions may determine where economic activities concentrate, corroborating research by Teixeira (2006) who found that in the Portuguese case industry is willing to move to new locations if transport costs drop below a certain level. This research aims to contribute to an understanding of the mechanism by considering the time-lagged differences in regional development before and after 20 years of infrastructural investment at both local and regional scales. With respect to methods, other research that matches this one more closely include González-González and Nogués (2019), who studied differential effects of transport investment in rural areas of Spain using accessibility variables like those in this research. Their goal was to find whether those investments translated onto greater territorial cohesion between urban and rural areas, so those authors did not go to the municipal level. Concerning methodology, the work closest to the present one is Lu et al. (2022), who also investigated urban-rural disparities, this time with

a geographic weighted regression and a two-step econometric model. The novelty of the present research is to consider both space and time-lagged variables simultaneously, while controlling for endogeneity and considering autocorrelation.

3. Methodology

To evaluate the impact of accessibility changes on regional development, the first step is to identify suitable variables. Data collection focused on the Center Region of Portugal, in the period 2001-2021. This region had a significant increase in road accessibility in that period, making it a prime candidate to establish whether accessibility had a significant impact on economic growth. The methodology to assess the relation between transport accessibility and regional development was based spatial statistics methods, namely a generalized spatial two-stage least-squares regression (GS2SLS) followed by a geographic weighted regression (GWR) regression to test for contrasting effects at the municipality level. Similarly to Lu et al. (2022), the GS2SLS paints a global picture, whereas the GWR goes to the local scale. The impact of accessibility on regional cohesion, i.e., whether it contributes to more equality among the municipalities was also investigated.

3.1 Variables and modelling

Gross value added (GVA) was selected as proxy for economic performance, an indicator that can be used to represent infrastructure effects on the economy (Byett et al., 2015; Zhou et al., 2022). Its application to the study of the transport/development relationship complements other research approaches that are based on input-output relations (see, e.g., Freiria et al. [2022] for a recent example) or infrastructure expenditure (see Melo et al. [2013] for a meta-analysis). Along with accessibility, the main explanatory variable, employment rate and elderly dependency rate (see below) were also selected as control variables. Other control variables were considered, such as private capital, but data on this variable was not available at the local scale. For all the variables, be it explanatory or dependent ones, the percentage difference between 2001-2021 was used in the calculations, i.e., $\Delta V = \frac{V_f - V_i}{V_i} \times 100\%$, not absolute change ($V_f - V_i$). Concerning explanatory variables, the methodology distinguishes two types of accessibility: relative potential accessibility and daily accessibility, as defined in

Table 1 and for reasons to be explained below. Relative potential accessibility emphasizes the relationship between the largest population centres and smaller ones, whereas daily accessibility counts the number of reachable opportunities on a daily basis. Table 1 and below provide details on the variables. Below note that two types of accessibility and three indicators thereof were considered.

Table 1: Description and source of the variables

Variable	Role	Designation	Period	Source
Gross Value Added	Dependent	Result of the production activity of an economy or of one of its industries, it is the difference between the value of output and the value of intermediate consumption, corrected for inflation.	2001-19*	(1,2)
Relative potential accessibility	Explanatory	Equation 1.	2001-21	(2)
Daily accessibility (30 min and 60 min)	Explanatory	Equation 2.	2001-21	(2)
Elderly dependency rate	Explanatory	Ratio of the number of elderly people at an age when they are generally economically inactive (i.e. aged 65 and over), compared to the number of people of working age (i.e. 15-64 years old).	2001-21	(2)
Employment	Explanatory	Total number of employees	2001-21	(2)

* Due to the COVID-19 pandemic impact on economic activity, pre-covid figures were preferred.

(1) Regulation (EU) 2022/590 of the European Parliament and of the Council.

(2) Portuguese Institute of Statistics (INE, 2022).

The relative potential accessibility indicator combines a gravity-based measure, initially proposed by Hansen (1959) and used extensively by many authors ever since (see, e.g., Rosik et al. [2020] for a recent instalment), with the degree to which two places are connected (Ingram, 1971) namely a municipality and a large population centre. It has an interpretation as the potential of opportunities for interaction between those two places and depends on the transport infrastructure and the spatial distribution of opportunities (i.e., land use component) (Geurs and van Wee, 2004). For the purpose of this article, it is expressed by eq. (1):

$$RP_i = \frac{P_j}{t_{ij}} \quad (1)$$

where RP_i represents the relative potential accessibility of municipality i , with j the district capital closest to i (the large centre); P_j the population of the closest district capital j ; and t_{ij} is the minimum travel time between i and j . Following previous work (Vickerman et al., 1999; Spiekermann and Neubauer, 2002; Jacobs-Crisioni et al., 2016; Beria et al., 2017), the population of the destination zone was taken as proxy for opportunities. Definition (1) complements other approaches to accessibility in the literature and is proposed because it embodies the Portuguese land use policy of privileging a polycentric layout of attractor points in the guise of district capitals (Marques et al., 2020). When j is a district capital the population to consider is that of j itself (self-potential) and t_{ij} is conventionally set to 1. This does not compromise comparability with non-district capitals because the variable is always a relative (time-lagged) variation, thus dimensionless. The choice of 1 for the distance decay exponent of t_{ij} follows Gutiérrez (2001), who suggests that value for regional studies because higher values put too much emphasis on short distances. Travel times were calculated for 2001 as well as for 2021, considering the type of road and the corresponding maximum speed allowed.

With respect to daily accessibility, this definition of accessibility was also considered relevant because it reflects the meeting of basic and daily needs based on the number of reachable opportunities within a travel time threshold that allows a return from destinations to the origin within a day. According to the latest census the average commuting time in Região Centro is 30 minutes (INE, 2022), a threshold also considered by Bertolini et al. (2005) and González-González and Nogués (2019). A 60-minute threshold was also used to test whether a larger value than the average commuting time had a significant impact on development. The daily accessibility assessment is a contour measure, inspired in González-González and Nogués (2019), that reads as follows:

$$D_i = \sum_{j \neq i} P_j \delta_{ij} \quad (2)$$

where P_j is the population of j (again as proxy for opportunities) and δ_{ij} is the Kronecker delta; 1 if the travel time between origin i and destination j sits below the given threshold; 0 otherwise. Following Gutiérrez (2001), the self-potential (case $j = i$) does not have a significant effect in an indicator with no distance decay, as D_i is, so including it or not depends on the purpose of the indicator. Because D_i is geared towards intermunicipal travel, the option was made not to include the self-potential.

3.2 Statistical assessment models – regional and local scale

Global assessments are commonly addressed with regression-based analyses, such as ordinary least-squares (OLS) (Goetz, 1992; Bennell and Prentice, 1993; Button and Taylor, 2000) or generalized two-stage least-squares (Brueckner, 2003; Bilotkach, 2015; Sheard, 2019). While these two methods have been widely used in problems with structure like that of this research, they disregarded spatial autocorrelation issues. To cater for spatial autocorrelation and also statistical endogeneity, this research used a generalized *spatial* two-stage least-squares method. The GS2SLS model contains spatially autocorrelated dependent variable and error terms. It reads as follows:

$$y = \alpha + \lambda Wy + \beta x + \varepsilon, \quad \varepsilon = \rho W\varepsilon + \mu \quad (3)$$

where y is the dependent variable; α an intercept term; ρWy the spatial lag (ρ is a coefficient of spatial autocorrelation and W the spatial contiguity matrix [first order queen contiguity]); x the explanatory variables with β regression coefficients; and $\varepsilon = \rho W\varepsilon + \mu$ the spatial autoregressive error term, with μ the independent and heteroskedastically distributed error. When λ and ρ are zero, the model has no spatial dependence and reduces to an OLS model.

The local effects are analysed with a geographically weighted regression. GWR provides local insights into to what extent the independent variables explain a dependent variable by allowing regression coefficients to vary over space (Fotheringham et al., 2003). Local parameters are estimated with a weighting scheme based on the Gaussian kernel that puts more weight on the spatial units that are closer to the unit in analysis than on the furthest units. The general form of a GWR model is

$$y = \alpha(u, v) + \beta(u, v)x + \varepsilon \quad (4)$$

where y is the dependent variable; α an intercept term; x the explanatory variables and β their regression coefficients; and ε the error term. The u, v are coordinates whereby α and β depend.

The GS2SLS and GWR models were used to analyse the dependent variable at the regional and local scales. Subsequently, an analysis on the levels of cohesion in the Center Region was carried out. Regional cohesion aims to promote equal opportunities for enterprises and citizens through the reduction of economic territorial imbalances (Pellegrini et al., 2013; Medeiros et al, 2016; González-González and Nogués, 2019). It is referred by the EU as the reduction of social and economic disparities between different geographic regions (Tömmel, 2016). In the context of this research, the degree of cohesion can be measured by disparities on the output variable, GVA, and is thus of economic nature.

Rather than relying only on global dispersion indicators to assess cohesion, which may not capture possible effects of accessibility, a different measure was needed to assess cohesion at a local scale. Several measures exist that can be used to define cohesion while being (possibly) sensitive to the effects of accessibility. This research used the GVA absolute distance to the mean, defined as follows: for each municipality i , its GVA absolute distance to the mean for 2001 and 2019 was calculated, i.e., $adm_i = |GVA_i - \overline{GVA}| \times 100\%$. Then the adm_i percent change during the time span was calculated and related to the change in the explanatory variables through a GS2SLS regression.

4. Case study and results

4.1 Case study

The methodology was applied to the NUTS2 Center Region of Portugal (Figure 1). The road network of the Center Region plays a relevant role in connecting the north and south of Portugal, the region itself, and linking Portugal with Spain, one of the main terrestrial accesses to the rest of Europe. The large population centres that define the relative potential accessibility attractors are those named in Figure 1 (Aveiro, Viseu, etc.). All of these are actual district capitals except for Covilhã, which is considered on par with a district capital in the official National Plan for land use policy and is thus treated as such for the purpose of this study (Marques et al., 2020).

The motorway network road length increased more than 100% in the years 2001 to 2021, going from 706 km to 1500 km respectively (Figure 1), with a high interchange density; average of a junction every 6 km, so there is very little tunnel effect (Komornicki and Stępnik, 2015). In 2000 the motorway road network was located mostly in the coastland, and for 20 years' efforts were carried out to better connect the coastland with mainland, as well as to promote a better connection among the cities located in the mainland interior (Guarda, Covilhã and Castelo Branco). The question is then to what extent did those efforts impact development at the regional and local scales, as well as cohesion.

As with most regional studies, there may be border effects from not considering interaction with the part of the country that lays outside the study area. However, since the study area is bordered by the Atlantic Ocean to the west and Spain to the east, these effects rate to minor. The analysis below does not suggest border effects influence the results, but that is not excluded and is a limitation of this study.

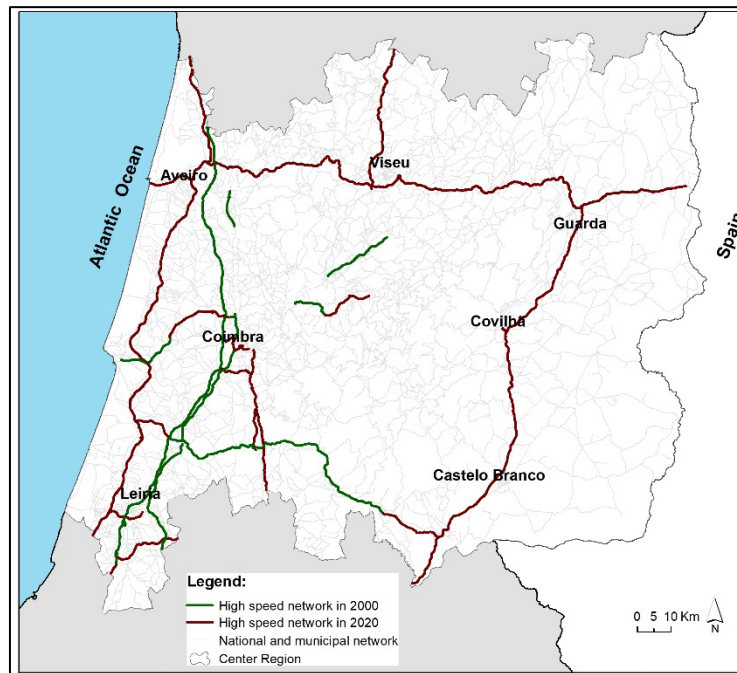


Figure 1: Road network in the Center Region of Portugal, 2001 and 2021.

4.2 Results

Prior to running the models, a brief descriptive overview of the main variables is given. The percentage changes regarding accessibility and economic growth are shown in Figures 2 and 3. Similar maps for the control variables can be found in the supplementary material (Fig. S1).

Concerning Figure 2, which exhibits the change in daily accessibility for 30 and 60 min, it is interesting to note that a considerable number of municipalities (29 out of 77) *lost* daily 30 min accessibility. Since no strips of road network were decommissioned, and given that accessibility is proxied by population, the loss must relate to population migration and total balance. Because the phenomenon does not happen for 60 min accessibility, the increase in motorway network length compensated for this loss, suggesting that part of that migration had other municipalities of the Center Region as destination. Several municipalities, located mostly in the East, had a growth of over 120% in daily accessibility, coinciding with areas where new roads were built. Figure 2b shows the population change due to migrations and total balance. Indeed, sizeable migrations have occurred during the study period, mostly southwards and towards the district capitals. Note however that these migrations did not fully offset population loss due to aging at the destinations. The fact that daily accessibility did not

dip further, and even increased near the new motorways, strengthens the case that those infrastructures compensated for migrations and overall population loss, in line with similar findings by Komornicki and Spiekermann (2018) on the Baltic states.

With respect to Figure 3 (left), which depicts relative potential accessibility changes, it is interesting to note that some district capitals (Coimbra, Guarda, Castelo Branco) registered a decrease of relative potential accessibility. Given the definition of this quantity, eq. (1), and that the travel time between municipalities did not decrease, one concludes that the population of the district capitals' closest neighbours must have decreased more than the travel time between the two in proportion. This conclusion might explain the migration identified when analysing Figure 2. Nevertheless, apart from the aforementioned district capitals, the new transport infrastructure did contribute to an increase of potential accessibility overall.

Finally, concerning gross added value (Figure 3, right), its increase was about +17% after correcting for inflation. Most municipalities gained productivity in that period, but some lost and the overall picture is somewhat unclear, making the look at statistical models necessary to try and understand the situation.

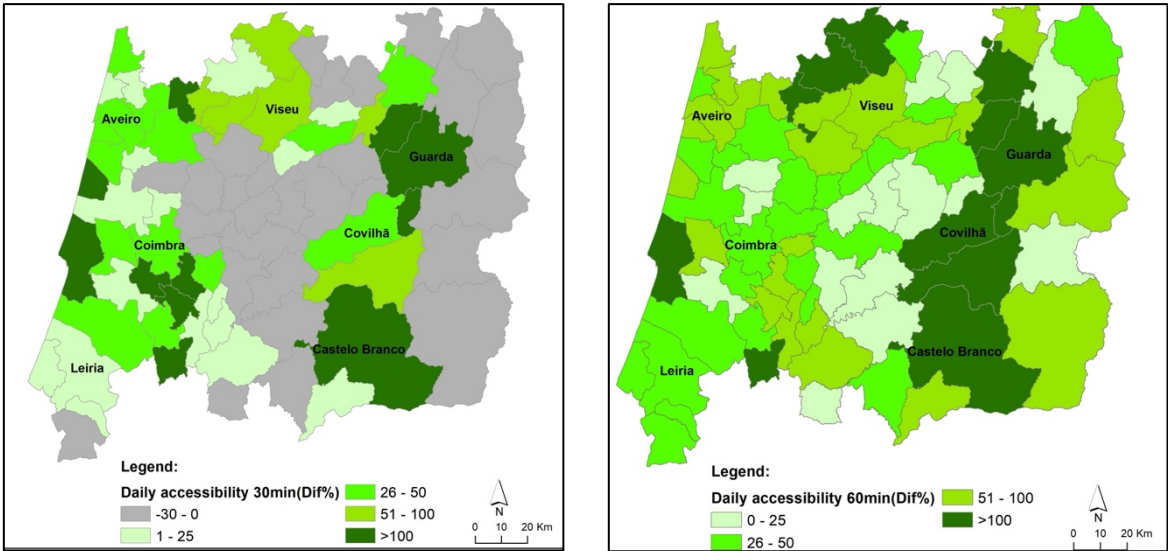


Figure 2: Daily accessibility 30 min (left) and daily accessibility 60 min (right) change between 2001 and 2021.

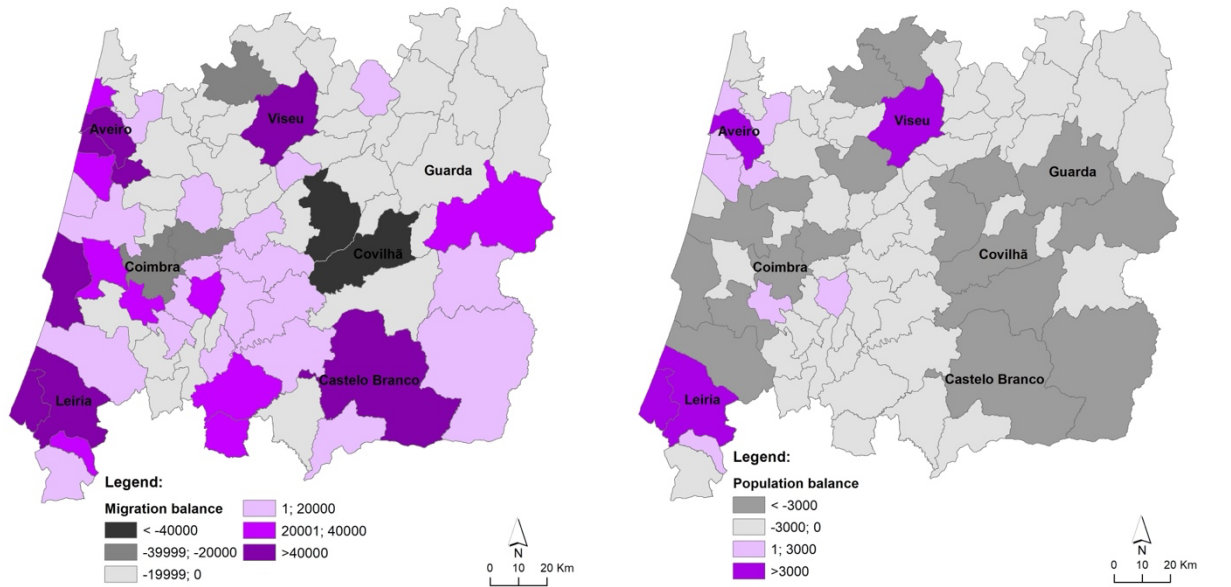


Figure 2b: Absolute population change between 2001 and 2021 due to migrations (left) and total balance (right).

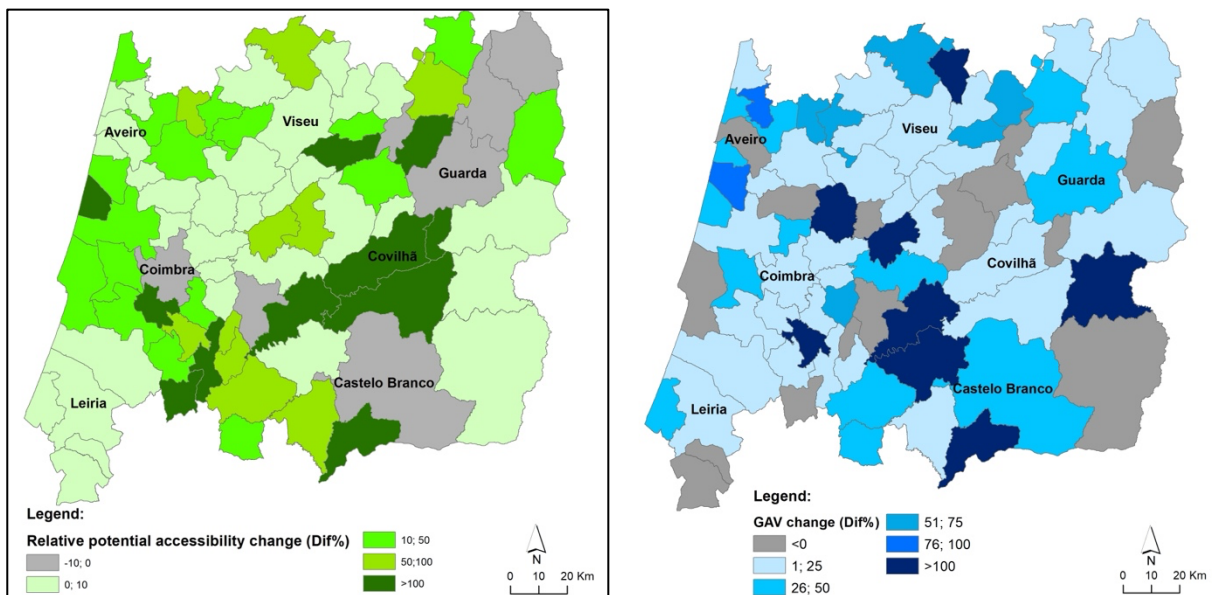


Figure 3: Relative potential accessibility change 2001-2021 (left) GVA change 2001-2019 (right).

Impact of accessibility changes on economic growth – Regional results

Table 2 below provides a summary of the GS2SLS results. A 5% significance was considered as threshold.

Table 2: Results for the GS2SLS regression model for GVA growth

Variable	Coefficient	p-value	Sig 5%
Intercept	159.996	< 0.001	Yes
Δ Relative potential accessibility	1.325	< 0.001	Yes
Δ Daily accessibility 60 min	-0.824	0.001	Yes
Δ Daily accessibility 30 min	0.158	0.062	No
Δ Employment	-1.014	0.002	Yes
Δ Elderly dependency rate	-0.963	0.005	Yes
λ (spatial lag)	0.421	0.190	No
ρ (error lag)	-0.725	0.185	No
R^2	0.290		

Overall, the GS2SLS is a reasonable fit ($R^2 \sim 30\%$) to the data and the table shows that relative potential accessibility was the only variable with a positive and significant effect on GVA growth. Daily accessibility had non-significant impacts at 30 min, but a negative one at 60 min, suggesting that the transport infrastructure investment contributed to generate capital flows towards some regions, in line with previous results in the literature. The control variables (employment; elderly dependency rate) were also found significant, justifying their inclusion in the model. As for the negative coefficient for employment, it is generally not expected that lower employment rates induce a GVA increase. However, since GVA is a measure of productivity, the negative coefficient suggests that the region modernized towards an economy of tradable goods of higher plus-values during those years. In the period in analysis the GAV grew, but the number of employees decreased from 1.259M to 1.092M (INE, 2022). Concerning the spatial autocorrelation coefficients for the GVA lag and statistical error, these were found to be non-significant, suggesting at best a weak geographical dependence of the model on neighbouring municipalities. It is important to note that this does not exclude the existence of significant local effects, as GS2SLS is a global spatial regression model and sometimes local effects get masked in those models (see e.g., Düzgün and Kemeç, 2008).

The GS2SLS model results allow for a response to the first research question, which was:

H1: Did the increase of road accessibility in the Center Region of Portugal in the period 2001-2021 have a significant impact on economic growth?

The answer is that the increase of road accessibility had mixed effects on GVA. The positive influence of relative potential accessibility was, to a point, offset by the negative influence of

daily 60 min accessibility, making it difficult to make a categorical claim. Possible explanations can be advanced for these effects that head in different directions, but before doing that it is advisable to look for local effects, as these may help understanding the phenomena.

Impact of accessibility changes on economic growth – Local results

Local effects are best explained by the GWR. A graphical depiction of amplitude and significance of local regression coefficients for the main explanatory variables is given in Figures 4-6. Values for the control variables GWR regression coefficients are given in the supplementary material (Figs. S2 and S3).

The GWR figures confirm the GS2SLS regional results and add a local dimension to them. The positive effect of relative potential accessibility on GVA is seen to be generally significant in the whole study area, except for a few municipalities in the interior north region. The negative effect of daily accessibility 60 minutes is now seen to be located to the mid- and deep-interior municipalities, whereas the daily accessibility 30 minutes has a slight significant effect in those same municipalities.

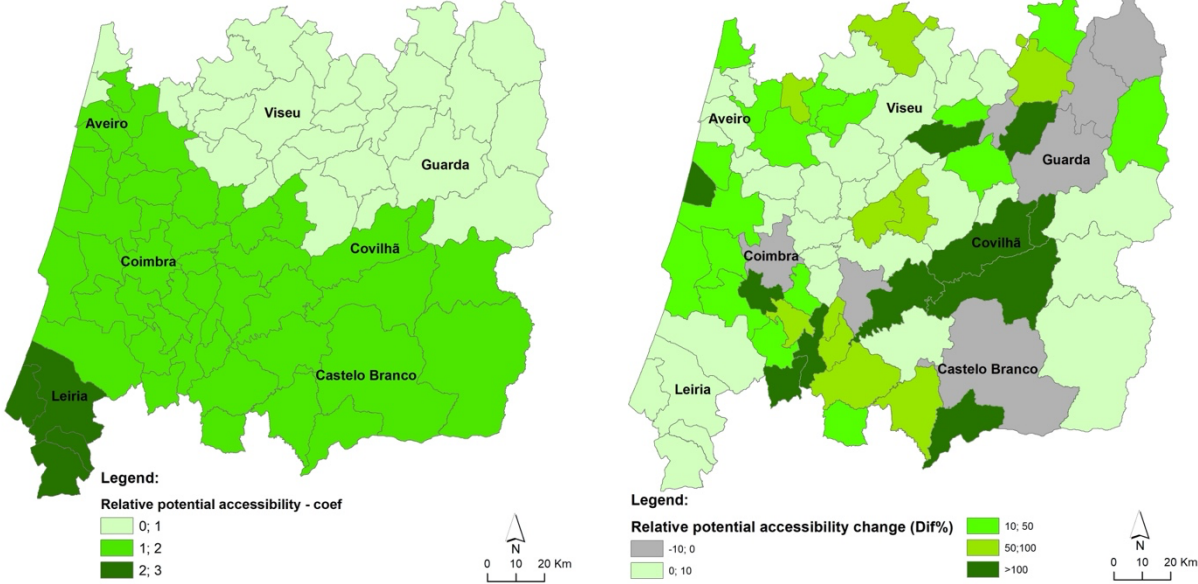


Figure 4: GWR results for relative potential accessibility – coefficients (left) and p-values (right)

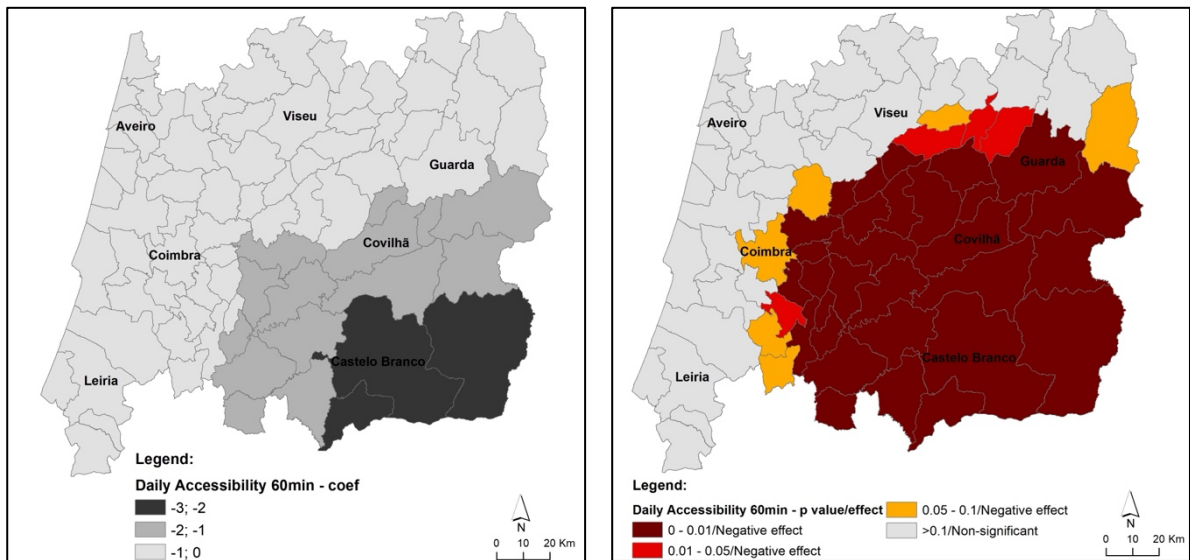


Figure 5: GWR results for daily accessibility 60 min – coefficients (left) and p-values (right)

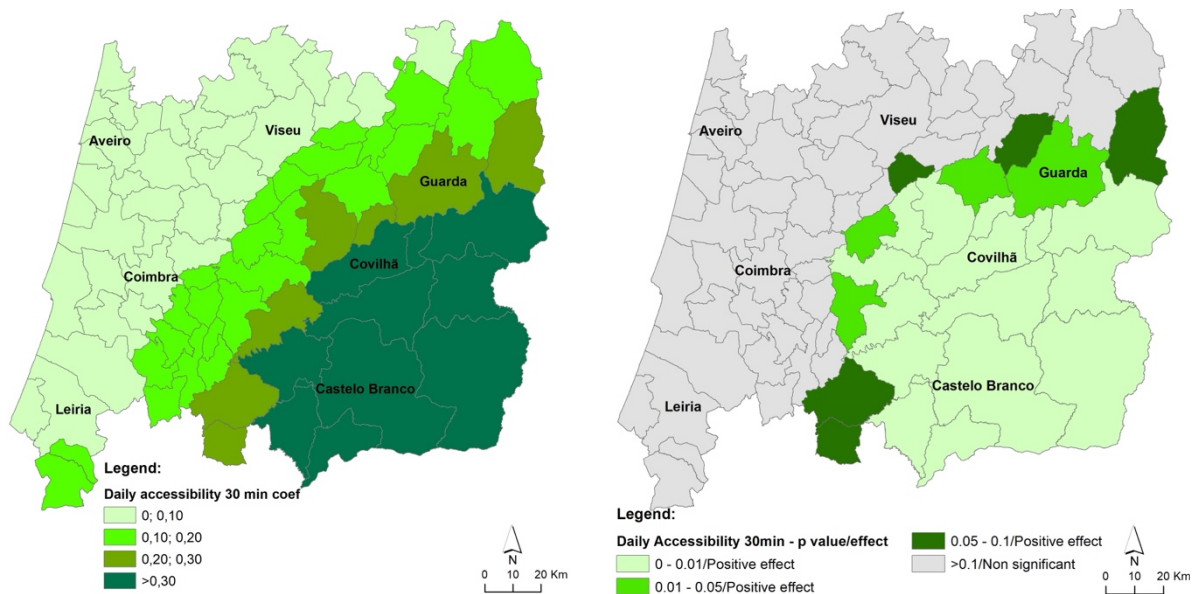


Figure 6: GWR results for daily accessibility 30 min – coefficients (left) and p-values (right)

The above remarks are essentially the response to research question 2, namely:

H2: Were there any contrasting effects at the municipality level, i.e., did the improved road network benefit some municipalities and caused a negative impact on others?

the answer being that relative potential accessibility had a widespread positive effect, whereas daily accessibility 60 minutes had a negative effect, concentrated in the interior. Interestingly, it is not the first-time findings such as these occur, González-González and Nogués (2019) also found contrasting signs for the Galician provinces, in the same direction

as this research: positive in the case of relative potential accessibility and negative in the case of daily accessibility. In all cases, the impact does not go much further from the areas where the new roads were constructed.

Impact of accessibility changes on regional cohesion – local scale

The final research question is now addressed, i.e.,

H3: Did the increase of accessibility in the Center Region of Portugal in the period 2001-2021 contribute to regional cohesion?

Concerning regional indicators for cohesion, the population-weighted Gini index for GVA in the Center Region evolved from 0.54 to 0.51 between 2001 and 2021, hinting at a decrease in inequality, in line with other economic measures estimates for the whole country. Portugal’s income Gini index decreased from 0.37 to 0.33 in the same time span. The same goes for measures such as the coefficient of variation, which did decrease from 1.56 to 1.44 between 2001 and 2021. However, these indicators do not consider accessibility. To assess the impact of accessibility on cohesion, the GS2SLS analysis presented in the methodology section was applied and the result is shown in Table 3.

Table 3: Results for the GS2SLS regression model for regional cohesion.

Variable	Coefficient	p-value	Sig 5%
Intercept	1.227	0.910	No
Δ Relative potential accessibility	-0.151	0.318	No
Δ Daily accessibility 60 min	0.136	0.386	No
Δ Daily accessibility 30 min	0.064	0.273	No
Δ Employment	-0.025	0.890	No
Δ Elderly dependency rate	0.015	0.942	No
λ (spatial lag)	-0.514	0.327	No
ρ (error lag)	0.508	0.161	No
R^2	0.058		

No significance was found in any variable, so cohesion appears to be disconnected from accessibility, and from control variables for that matter. However, the model fit quality is poor ($R^2 \sim 6\%$) and this does not appear to be solved by considering similar dispersion measures, as GS2SLS models based on, e.g., relative distance to the mean or quadratic distance to the mean also have low significance and poor fit.

Better models notwithstanding, at this point it can only be said that it is unlikely that accessibility improvements in the Center Region contributed to reduce asymmetries. It is possible that this may be a reflection of accessibility undermining local development.

5. Discussion

The case study revealed that accessibility improvements had a rather complex effect on GVA growth. If, on the one hand, relative potential accessibility had to a positive, widespread effect on GVA overall, on the other hand, daily 60 minutes accessibility had a negative effect, mainly concentrated on the mid and interior municipalities. Daily 30 minutes accessibility was found globally non-significant, but some pockets exist in the interior where it had a significant and mild positive effect on GVA. Albeit these results seem strange at first, it is not the first time that apparently contradictory conclusions arise from studies relating accessibility and development (González-González and Nogués, 2019). That is, in fact, to be expected when the relation between variables is complex, something this research confirms. Still, possible explanations for the findings are now presented.

Relative potential accessibility, having a generalized effect over the study area, suggests that the decrease in travel time towards district capitals is responsible for GVA growth, as the other factor of relative potential accessibility, population, has had flows occurring in the 20-year period and was thus superseded by travel time decrease. This decrease may then foster GVA growth by increasing the interaction between neighbouring municipalities in terms of goods and services.

Concerning daily accessibility, the threshold times of 30 and 60 minutes are considerably different. The time buffer for daily commuting is circa 60 minutes in total, i.e., circa 30 minutes each way (INE, 2022). Larger commuting times make it more likely that a person changes residence (Shuai, 2012) and she tends to move to places with higher road accessibility, as shown by Spiekermann and Neubauer (2002) for Denmark and Kotavaara et al. (2011) for Finland, a conclusion this research supports. An increase of daily accessibility of 30 minutes

opens job opportunities within commuting range and is thus expected to increase GVA. This is indeed seen in the GWR and it is not surprising the effect is concentrated in the interior region, which is where a new motorway was constructed. Data on the variation of commuting population between 2001-21 confirms that commuting increased in general, and it increased the most in municipalities close to the new motorways (see supplementary material, Fig. S4). Daily accessibility 60 minutes is quite different. Service areas' sizes are roughly proportional to time-squared (t^2), so going from 30 minutes to 60 minutes is expected to increase the interaction opportunities (e.g., services, jobs) four-fold, or three times as many when comparing 60 to 30 minutes. However, having a one-way commute of 30-60 minutes is not attractive and a person that accepts a job offer may start-off by making a long commute but, in time, is likely to move to a municipality closer to that job. So, increasing daily accessibility 60 minutes can lead to more job offers outside the 30-minute commute and induce population flows that typically benefit the more prosperous municipalities (recall fig. 2b), an effect other authors already found: sometimes, better accessibility can have a local negative economic effect on the more depressed areas. The increase in daily accessibility also brought faraway job opportunities to within the 60 min threshold, increasing the likelihood that people find new jobs in the more prosperous municipalities, deepening GVA asymmetries. The above observations may well be the reason a negative coefficient was found for daily accessibility 60 minutes both in the GS2SLS and GWR models, and this is consistent with the effect again being stronger in the interior, because of the new motorways constructed there. The effect is, however, not so strong along the northernmost east/west motorway, which may signal a border effect and warrant further investigation.

Finally, with respect to cohesion, results show that accessibility has not, in any form, made the Center Region more cohesive. This result is in line with previous work by Ribeiro et al (2010) and Stepniak and Rosik (2013), who also concluded that a direct relationship between the improvement in accessibility and regional cohesion cannot be established. Ortega et al (2012) demonstrated that accessibility changes can have a positive effect on cohesion at national scale, but negative at regional scale. However, that claim could not be verified in the case study because the study did not encompass the whole country.

6. Summary and future work

This research sought to deepen the understanding on how accessibility shapes development. Two spatial models, namely generalized spatial two-stage least squares and geographic weighted regression, were applied to a case study, the Center Region of Portugal, to ascertain to what degree road infrastructure improvements contributed to regional development. Using percent increase between 2001 and 2021 as model variables, with gross value added as the dependent one, and three accessibility measures and two demographic control variables as explanatory ones, results demonstrated that accessibility changes can have mixed impacts on GVA growth, depending on how one defines that accessibility. Furthermore, significant local effects were also found, mostly concentrated where new motorways were built. The spatial models cater for autocorrelation and endogeneity, two issues the literature on the subject is starting to consider. Both models agree on the direction and significance of the impact of accessibility on GVA. The GS2SLS global model provided an overview of the regional relation between and endogeneity but was unable to capture the local effects which the GWR encountered.

Relative potential accessibility, which is proportional to travel time between neighbouring municipalities, has a net positive effect, whereas daily 30 and 60-minutes accessibility, defined in terms of a contour measure, have opposite effects: positive for 30-minutes, negative for 60-minutes, both concentrated in the interior of the Center Region of Portugal. A possible explanation for this discrepancy in direction was given in terms of service area size, in that 30-minutes commutes are acceptable and positive for GVA, whereas 60-minutes commutes cover a much wider area but are undesirable, encouraging population flows towards the more prosperous municipalities, thus causing a negative effect on GVA.

Results and their interpretation go in line with previous findings that more accessibility is generally positive, but does not always lead to more development, precisely because it might induce migrations and more commuting, i.e., more people contributing to GVA outside their municipality. The novelty of this research was to relate accessibility types to directions of impact on development (positive or negative), along with advancing a possible explanation for the discrepancies. The research went beyond global analyses and identified, in the same

region, municipalities that were positively impacted by accessibility changes and others that were negatively impacted.

Concerning limitations and future directions, this work only considered the impact of the accessibility change in the period 2001-2021, but the National Road Plan foresees in the medium term the construction of other roads whose route is already defined. Further research could assess the impact on GVA of a future level of accessibility provided by these new roads. This direction of research goes in tandem with expanding the study to the whole country of Portugal, which would allow for a broader look at the data and mitigate eventual border effects, such as those that may be happening at the north of the study region. It could also shed light on whether the discrepancy between 30 and 60-minute daily accessibility holds across larger, country-scale datasets. Those datasets could also help further understanding the relationship between relative potential accessibility and GVA, as well as clarifying the impact of accessibility on cohesion, which for the moment remains poorly understood. Another limitation is related with data availability. For instance, local road investments were not considered in this research due to lack of reliable data for the study period. Also, Melo et al. (2013) demonstrated that the effect of transport infrastructure is not the same for all industry groups. Therefore, it would make sense to include private capital as explanatory variable. However, limitations apply for such a study, as private capital data is currently not available at the local scale. We hope to address some of these issues in the near future.

References

- Álvarez-Ayuso, I. C., Condeço-Melhorado, A. M., Gutiérrez, J., & Zofío, J. L. (2016). Integrating network analysis with the production function approach to study the spillover effects of transport infrastructure. *Regional Studies*, 50(6), 996-1015. <https://doi.org/10.1080/00343404.2014.953472>
- Arbués, P., Baños, J. F., & Mayor, M. (2015). The spatial productivity of transportation infrastructure. *Transportation Research Part A: Policy and Practice*, 75, 166-177. <https://doi.org/10.1016/j.tra.2015.03.010>
- Aschauer, D.A. (1989). Is public expenditure productive? *Journal of monetary economics*, 23(2), 177-200. [https://doi.org/10.1016/0304-3932\(89\)90047-0](https://doi.org/10.1016/0304-3932(89)90047-0)

- Benell, D. W., & Prentice, B. E. (1993). A regression model for predicting the economic impacts of Canadian airports. *Logistics and transportation review*, 29(2), 139. Available online at: <https://trid.trb.org/View/382227>
- Beyazit, E. (2015). Are wider economic impacts of transport infrastructures always beneficial? Impacts of the Istanbul Metro on the generation of spatio-economic inequalities. *Journal of Transport Geography*, 45, 12-23. <https://doi.org/10.1016/j.jtrangeo.2015.03.009>
- Beria, P., Debernardi, A., & Ferrara, E. (2017). Measuring the long-distance accessibility of Italian cities. *Journal of Transport Geography*, 62, 66-79. <https://doi.org/10.1016/j.jtrangeo.2015.03.009>
- Bertolini, L., Le Clercq, F., & Kapoen, L. (2005). Sustainable accessibility: a conceptual framework to integrate transport and land use plan-making. Two test-applications in the Netherlands and a reflection on the way forward. *Transport Policy*, 12(3), 207-220. <https://doi.org/10.1016/j.tranpol.2005.01.006>
- Bilotkach, V. (2015). Are airports engines of economic development? A dynamic panel data approach. *Urban Studies*, 52(9), 1577-1593. <https://doi.org/10.1177/0042098015576869>
- Boarnet, M. G. (1998). Spillovers and the locational effects of public infrastructure. *Journal of Regional Science*, 38(3), 381-400. <https://doi.org/10.1111/0022-4146.00099>
- Brakman, S., Garretsen, H., & van Marrewijk, C. (2021). New Economic Geography After 30 Years. In: *Handbook of Regional Science* (pp. 1223-1245). Berlin, Heidelberg: Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-662-60723-7_39
- Brueckner, J. K. (2003). Airline traffic and urban economic development. *Urban Studies*, 40(8), 1455-1469. <https://doi.org/10.1080/0042098032000094388>
- Button, K. (1998). Infrastructure investment, endogenous growth and economic convergence. *The annals of regional science*, 32, 145-162. Available online: <https://link.springer.com/article/10.1007/s001680050067>
- Button, K., & Taylor, S. (2000). International air transportation and economic development. *Journal of air transport management*, 6(4), 209-222. [https://doi.org/10.1016/S0969-6997\(00\)00015-6](https://doi.org/10.1016/S0969-6997(00)00015-6)

- Byett, A. J., Laird, J., Stroombergen, A., & Trodd, S. (2015). *Assessing new approaches to estimating the economic impact of transport interventions using the gross value added approach*. New Zealand Transport Agency, research report No. 566. Available online at: <https://www.nzta.govt.nz/assets/resources/research/reports/566/docs/566.pdf>
- Chandra, A., & Thompson, E. (2000). Does public infrastructure affect economic activity?: Evidence from the rural interstate highway system. *Regional science and urban economics*, 30(4), 457-490. [https://doi.org/10.1016/S0166-0462\(00\)00040-5](https://doi.org/10.1016/S0166-0462(00)00040-5)
- Crescenzi, R., & Rodríguez-Pose, A. (2012). Infrastructure and regional growth in the European Union. *Papers in regional science*, 91(3), 487-513. <https://doi.org/10.1111/j.1435-5957.2012.00439.x>
- Delgado, M. J., & Álvarez, I. (2007). Network infrastructure spillover in private productive sectors: evidence from Spanish high capacity roads. *Applied Economics*, 39(12), 1583-1597. <https://doi.org/10.1080/00036840500486557>
- Düzgün, H., Kemeç, S. (2008). Spatial and Geographically Weighted Regression. In: Shekhar, S., Xiong, H. (eds) *Encyclopedia of GIS*. Springer, Boston, MA. https://doi.org/10.1007/978-0-387-35973-1_1242
- European Commission (2023) Territorial Agenda 2023. Available online at: https://territorialagenda.eu/wp-content/uploads/TA2030_jun2021_en.pdf
- Ferrara, A. R., McCann, P., Pellegrini, G., Stelder, D., & Terribile, F. (2017). Assessing the impacts of Cohesion Policy on EU regions: A non-parametric analysis on interventions promoting research and innovation and transport accessibility. *Papers in Regional Science*, 96(4), 817-841. <https://doi.org/10.1111/pirs.12234>
- Fotheringham, A. S., Brunsdon, C., & Charlton, M. (2003). *Geographically weighted regression: the analysis of spatially varying relationships*. John Wiley & Sons. <https://www.jstor.org/stable/30139578>
- Freiria, S., Sousa, N., & Calvo-Poyo, F. (2022). Spatial analysis of the impact of transport accessibility on regional performance: A study for Europe. *Journal of Transport Geography*, 102, 103371. <https://doi.org/10.1016/j.jtrangeo.2022.103371>

- Gagliardi, L., & Percoco, M. (2017). The impact of European Cohesion Policy in urban and rural regions. *Regional Studies*, 51(6), 857-868. <https://doi.org/10.1080/00343404.2016.1179384>
- Geurs, K. T., & Van Wee, B. (2004). Accessibility evaluation of land-use and transport strategies: review and research directions. *Journal of Transport geography*, 12(2), 127-140. <https://doi.org/10.1016/j.jtrangeo.2003.10.005>
- Goetz, A. R. (1992). Air passenger transportation and growth in the US urban system, 1950–1987. *Growth and change*, 23(2), 217-238. <https://doi.org/10.1111/j.1468-2257.1992.tb00580.x>
- González-González, E., & Nogués, S. (2019). Long-term differential effects of transport infrastructure investment in rural areas. *Transportation Research Part A: Policy and Practice*, 125, 234-247. <https://doi.org/10.1016/j.tra.2018.01.026>
- Gutiérrez, J. (2001). Location, economic potential and daily accessibility: an analysis of the accessibility impact of the high-speed line Madrid–Barcelona–French border. *Journal of Transport Geography*, 9(4), 229-242. [https://doi.org/10.1016/S0966-6923\(01\)00017-5](https://doi.org/10.1016/S0966-6923(01)00017-5)
- Hansen, W. G. (1959). How accessibility shapes land use. *Journal of the American Institute of planners*, 25(2), 73-76. <https://doi.org/10.1080/01944365908978307>
- Holtz-Eakin, D., & Schwartz, A.E. (1995). Spatial productivity spillovers from public infrastructure: evidence from state highways. *International Tax and Public Finance*, 2(3), 459-468. <https://doi.org/10.1007/BF00872777>
- Ingram, D. R. (1971). The Concept of Accessibility: A Search for an Operational Form. *Regional Studies*, 5, 101-107. <https://doi.org/10.1080/09595237100185131>
- Instituto Nacional de Estatística – INE (2022). *Censos 2021- XVI Recenseamento Geral da População. VI Recenseamento Geral da Habitação*. https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_publicacoes&PUBLICACOESpub_boui=65586079&PUBLICACOESmodo=2
- Jacobs-Crisioni, C., Batista e Silva, F., Lavallo, C., Baranzelli, C., Barbosa, A., & Perpiña Castillo, C. (2016). Accessibility and territorial cohesion in a case of transport infrastructure

- improvements with changing population distributions. *European Transport Research Review*, 8(1), 1-16. <https://doi.org/10.1007/s12544-016-0197-5>
- Komornicki, T., & Spiekermann, K. (2018). Accessibility of the Baltic Sea Region Past and future dynamics. VASAB Research Report. Dortmund. Available online at: https://vasab.org/wp-content/uploads/2019/07/VASAB_Accessibility_Report_2018.pdf
- Komornicki, T., & Goliszek, S. (2023). New transport infrastructure and regional development of Central and Eastern Europe. *Sustainability*, 15(6), 5263. <https://doi.org/10.3390/su15065263>
- Komornicki, T., & Stępnia, M. (2015). New investment projects in the road corridors and the improvement of the potential accessibility in Poland. *Europa XXI*, 28, 33-52. <http://dx.doi.org/10.7163/Eu21.2015.28.2>
- Kotavaara, O., Antikainen, H., & Rusanen, J. (2011). Population change and accessibility by road and rail networks: GIS and statistical approach to Finland 1970–2007. *Journal of Transport Geography*, 19(4), 926-935. <https://doi.org/10.1016/j.jtrangeo.2010.10.013>
- Lu, H., Zhao, P., Hu, H., Zeng, L., Wu, K. S., & Lv, D. (2022). Transport infrastructure and urban-rural income disparity: A municipal-level analysis in China. *Journal of Transport Geography*, 99, 103292. <https://doi.org/10.1016/j.jtrangeo.2022.103292>
- Marques, T., Saraiva, M., Ribeiro, D., Amante, A., Silva, D., & Melo, P. (2020). Accessibility to services of general interest in polycentric urban system planning: the case of Portugal. *European Planning Studies*, 28(6), 1068-1094. <https://doi.org/10.1080/09654313.2019.1658718>
- Medeiros, E. (2017). European Union cohesion policy and Spain: A territorial impact assessment. *Regional Studies*, 51(8), 1259-1269. <https://doi.org/10.1080/00343404.2016.1187719>
- Melo, P., Graham, D., & Brage-Ardao, R. (2013). The productivity of transport infrastructure investment: A meta-analysis of empirical evidence. *Regional science and urban economics*, 43(5), 695-706. <https://doi.org/10.1016/j.regsciurbeco.2013.05.002>
- Mennis, J. (2006). Mapping the results of geographically weighted regression. *The Cartographic Journal*, 43(2), 171-179. <https://doi.org/10.1179/000870406X114658>

- Monzon, A., Lopez, E., & Ortega, E. (2021). Has HSR improved territorial cohesion in Spain? An accessibility analysis of the first 25 years: 1990–2015. In *Spatial Implications and Planning Criteria for High-Speed Rail Cities and Regions. European Planning Studies*, 27(3), 513–532. <https://doi.org/10.1080/09654313.2018.1562656>
- Moreno, R., & López-Bazo, E. (2007). Returns to local and transport infrastructure under regional spillovers. *International Regional Science Review*, 30(1), 47-71. <https://doi.org/10.1177/0160017606296728>
- Munnell, A.H. (1992). Policy watch: infrastructure investment and economic growth. *Journal of Economic Perspectives*, 6(4), 189-198. <https://doi.org/10.1257/jep.6.4.189>
- Muvawala, J., Sebukeera, H., & Ssebulime, K. (2021). Socio-economic impacts of transport infrastructure investment in Uganda: Insight from frontloading expenditure on Uganda's urban roads and highways. *Research in Transportation Economics*, 88, 100971. <https://doi.org/10.1016/j.retrec.2020.100971>
- Nogués, S., & González-González, E. (2022). Are current road investments exacerbating spatial inequalities inside European peripheral regions? *European Planning Studies*, 30(10), 1845-1871. <https://doi.org/10.1080/09654313.2021.1934407>
- Pellegrini, G., Terribile, F., Tarola, O., Muccigrosso, T., & Busillo, F. (2013). Measuring the effects of European Regional Policy on economic growth: A regression discontinuity approach. *Papers in Regional Science*, 92(1), 217-233. <https://doi.org/10.1111/j.1435-5957.2012.00459.x>
- Pereira, A.M., & Roca-Sagalés, O. (2003). Spillover effects of public capital formation: evidence from the Spanish regions. *Journal of Urban economics*, 53(2), 238-256. [https://doi.org/10.1016/S0094-1190\(02\)00517-X](https://doi.org/10.1016/S0094-1190(02)00517-X)
- Ribeiro, A., Antunes, A. P., & Páez, A. (2010). Road accessibility and cohesion in lagging regions: empirical evidence from Portugal based on spatial econometric models. *Journal of Transport Geography*, 18(1), 125-132. <https://doi.org/10.1016/j.jtrangeo.2009.03.002>
- Rokicki, B., Haddad, E.A., Horridge, J.M., & Stępnia, M. (2021). Accessibility in the regional CGE framework: the effects of major transport infrastructure investments in Poland. *Transportation*, 48(2), 747-772. <https://doi.org/10.1007/s11116-019-10076-w>

- Rosik, P., Pomianowski, W., Komornicki, T., Goliszek, S., Szejgiec-Kolenda, B., & Duma, P. (2020). Regional dispersion of potential accessibility quotient at the intra-European and intranational level. Core-periphery pattern, discontinuity belts and distance decay tornado effect. *Journal of Transport Geography*, 82, 102554. <https://doi.org/10.1016/j.jtrangeo.2019.102554>
- Rosik, P., & Wójcik, J. (2022). Transport Infrastructure and Regional Development: A Survey of Literature on Wider Economic and Spatial Impacts. *Sustainability*, 15(1), 548. <https://doi.org/10.3390/su15010548>
- Sheard, N. (2019). Airport size and urban growth. *Economica*, 86(342), 300-335. <https://doi.org/10.1111/ecca.12262>
- Shuai, X. (2012). Does Commuting Lead to Migration? *The Journal of Regional Analysis and Policy*, 42(3), 237-250. <https://jrap.scholasticahq.com/article/7962>
- Silva, C., & Altieri, M. (2022). Is regional accessibility undermining local accessibility? *Journal of transport geography*, 101, 103336. <https://doi.org/10.1016/j.jtrangeo.2022.103336>
- Sloboda, B.W., & Yao, V.W. (2008). Interstate spillovers of private capital and public spending. *The Annals of Regional Science*, 42(3), 505-518. <https://doi.org/10.1007/s00168-007-0181-z>
- Skorobogatova, O., & Kuzmina-Merlino, I. (2017). Transport infrastructure development performance. *Procedia Engineering*, 178, 319-329. <https://doi.org/10.1016/j.proeng.2017.01.056>
- Spiekermann, K., & Neubauer, J. (2002). European accessibility and peripherality: Concepts, models and indicators. Nordregio. URL: <https://www.diva-portal.org/smash/get/diva2:700463/FULLTEXT01.pdf> (accessed 12 jul 2024).
- Stepniak, M., & Rosik, P. (2013). Accessibility improvement, territorial cohesion and spillovers: a multidimensional evaluation of two motorway sections in Poland. *Journal of Transport Geography*, 31, 154-163. <https://doi.org/10.1016/j.jtrangeo.2013.06.017>
- Teixeira, A., (2006). Transport policies in light of the new economic geography: The Portuguese experience. *Regional Science and Urban Economics*, 36(4), 450-466. <https://doi.org/10.1016/j.regsciurbeco.2006.01.002>

- Tömmel, I. (2016). The Commission and Cohesion Policy. *Handbook on Cohesion Policy in the EU*, 107-120. <https://doi.org/10.4337/9781784715670.00021>
- Tsamboulas, D., Vrenken, H., & Lekka, A. M. (2007). Assessment of a transport policy potential for intermodal mode shift on a European scale. *Transportation Research Part A: Policy and Practice*, 41(8), 715-733. <https://doi.org/10.1016/j.tra.2006.12.003>
- Vickerman, R. (2017). Beyond cost-benefit analysis: the search for a comprehensive evaluation of transport investment. *Research in Transportation Economics*, 63, 5-12. <https://doi.org/10.1016/j.retrec.2017.04.003>
- Vickerman, R., Spiekermann, K., & Wegener, M. (1999). Accessibility and economic development in Europe. *Regional studies*, 33(1), 1-15. <https://doi.org/10.1080/00343409950118878>
- Zhou, Y., Zhang, L., & Chiaradia, A. J. (2022). Estimating wider economic impacts of transport infrastructure investment: Evidence from accessibility disparity in Hong Kong. *Transportation Research Part A: Policy and Practice*, 162, 220-235. <https://doi.org/10.1016/j.tra.2022.05.014>