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Twenty years of accessibility improvements. The case of the Spanish motorway building programme

Adelheid Holl *

Department of Town and Regional Planning, University of Sheffield, Sheffield S10 2TN, UK

Abstract

This paper presents an exploratory spatial data analysis of accessibility impacts of a large-scale national motorway building programme. Accessibility is calculated for Spanish municipalities from 1980 to 2000 using two indicators: motorway network access and market potential accessibility. The average distance from municipalities to their nearest motorway has been reduced markedly over this period. Market potential accessibility maps show that there have been gains in all locations, but some of the highest gains occurred in some of the more peripheral regions. A review of the theoretical and empirical literature on the economic impacts of transport investments indicates important implications for regional development.

Keywords: Transport infrastructure; GIS; Accessibility

1. Introduction

Accessibility is the extent to which spatial separation can be overcome. It defines opportunities of exchange made available to people and firms. The concept of accessibility has a long tradition in urban and regional science. From the urban point of view it is a key variable in the determination of urban land rents and densities (Alonso, 1964). From a regional perspective, accessibility plays an important role for development and for the spatial distribution of economic activity (Krugman, 1991; Fujita et al., 1999).

Lack of access is identified as a main impediment to the economic competitiveness of peripheral lagging regions in Europe (European Commission, 1999). Improvements in transport infrastructure are, therefore, seen as a key element in their economic development and in overcoming spatial imbalances. In this context, transport infrastructure has re-emerged as a key policy issue in Europe and Spain stands out as a notable example. The country has developed an ambitious road building programme, increasing its motorway network from 1933 km in 1980 to over 9000 km by 2000.[1] Such large-scale transport projects have major implications for spatial planning. This is, for example, emphasised in the European Spatial Development Perspective, which identifies access to infrastructure as one of the main areas for an integrated spatial development policy agenda (European Communities, 1998).

This paper contributes to the literature in three important ways. First, the accessibility impacts of a major national motorway construction programme are analysed. Many studies have focused on the accessibility impacts of individual transport projects, but there has been relatively less work on accessibility impacts of transport investments programmes at a national scale.

Second, the period of analysis covers 20 years over which the main Spanish cities became linked by the motorway network. This is a much longer period of analysis than

* Present address: Fundación de Estudios de Economía Aplicada (FEDEA), Jorge Juan, 46, 28001 Madrid, Spain. Tel.: +34 91 435 90 20; fax: +34 91 577 95 75.
E-mail address: a.holl@fedea.es

[1] In addition, 1400 km of dual carriageway roads have been built over this period.

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in most previous studies. In terms of planning, two major sub-periods can be distinguished. The ''Plan General de Carreteras'' was the first major motorway building programme and was adopted in 1983. Implementation started in 1984, with the programming phase covering the period up to 1991. The main strategy of the plan was to upgrade the principal road connections to free motorways and to provide the basic radial motorway network linking the major cities to the capital, Madrid. However, it was not until the late 1980s that the first important motorway links of this major road building programme opened to traffic and until 1994 that the main motorway connections that had been planned were finished. In 1993, the government introduced the ''Plan Director de Infraestructuras'', that was to complete the primary motorway network. The current planning period 2000–2010 continues the extension of the motorway network through the provision of a complementary finer mesh network.

Third, accessibility indicators are calculated at a very detailed geographical level. Most previous studies have calculated accessibility measures for fairly large spatial units. Recent research increasingly points to a need for a more micro-level based analysis (Weisbrod and Treyz, 1998; Banister and Berechman, 2000). Similarly, Rienstra et al. (1998); Rietveld and Bruinsma (1998) and Holl (2004a) also call for more detailed analyses at lower levels of spatial disaggregation in order to shed some more light on impacts of transport infrastructure improvements not only at the inter-regional level but also intra-regionally. Vickerman (1995), for example, argues that with the development of a higher order transport network such as the Trans-European Transport Networks (TENs) intra-regional distribution effects are becoming increasingly pronounced depending on differences in access to the new networks.

Information at a detailed geographical level on accessibility impacts of motorway improvements at a national scale over a long period is important for the correct evaluation of transport programmes and should be of interest to planners and policy makers. The next section briefly discusses some of the most widely used accessibility indicators. Section 3 first describes the calculation of the indicators used for the present analysis and then presents the results of the exploratory analysis of accessibility impacts of the large-scale motorway building programme that was carried out in Spain over the last 20 years. Accessibility has often been argued to be a key factor for balanced economic development. Section 4 reviews the literature on regional development impacts of accessibility improvements and ways they affect the spatial distribution of economic activity. The final section concludes.

2. Accessibility measures

Accessibility measures are an important tool for planners and policy makers in integrating spatial planning and transport planning (Halden, 2002). In practice, a wide range of accessibility measures have been used in the literature and Bruinsma and Rietveld (1998) and more recently Geurs and Wee (2004) provide excellent reviews. This is because there is no single definition of accessibility, and consequently it has been measured in many ways. Here location-based measures will be applied that capture locations' spatial relation to the transport infrastructure network and to other destinations. A basic distinction can be drawn between distance measures (network access, travel time measures) and potential accessibility measures. As stressed by Gutiérrez (2001) these indicators offer complementary information about different aspects of accessibility benefits that are derived from transport infrastructure and its improvement.

2.1. Network access

Simple measures of accessibility take the distance one has to travel to a specific transport network (Lutter et al., 1992; CEDRE, 1993). Such measures reflect opportunities for travel and transport and constitute an important part of the overall accessibility of an area (Vickerman, 1994; Murray et al., 1998). Murray et al. (1998) and Murray (2001) stress the importance of network access as an important service performance measure of public transportation. Access measures can provide important information, particularly where the transport network is not ubiquitous, as this is the case for the road network in Spain. Gutiérrez and Urbano (1996), for example, in a European accessibility study calculate corridors of 40 km straight line distance to the trans-European road network. Their results show that in 1992, peripheral countries such as Spain, Portugal and Greece still displayed large areas outside these corridors.

2.2. Travel cost measures

The second measure of accessibility that has been frequently used in the literature are travel cost measures. Travel cost measures not only take into account network access, but also travel along the networks. Frequently, travel cost measures are based on travel time as a proxy for the generalised travel cost. Accessibility of an area or a node is given by the travel cost between a node and another node or a weighted average of travel cost to a number of nodes in the network. Travel cost measures are sensitive to the demarcation of the study area and the selection of destinations (Bruinsma and Rietveld, 1998). If the destinations are chosen too narrowly, relevant nodes could be missing, while when too many nodes are included the indicators could be influenced by irrelevant nodes. The problem applies particularly to the simplest case of travel cost measures where no distinction between the size of the selected destinations is made. The concept is better suited for situations where the effect of a network improvement on accessibility to particular destinations is analysed. It has been applied to measure, for example, the travel time to the nearest city over a given size or to a specific market

(Guimarães et al., 2000; Buurman and Rietveld, 1999). In European wide studies the average travel cost approach has been applied, for example, by Gutiérrez and Urbano (1996).

2.3. Market potential accessibility

The problem of arbitrary destination selection in the case of travel time measures is overcome in the case of market potential accessibility measures. Harris (1954) showed that market potential is determined by the distance to and the size of market demand in alternative locations. Compared to travel cost measures, market potential accessibility measures take into account that destinations at greater distance provide diminishing opportunities. Here, the attraction of a destination increases with size but decreases with distance. For a detailed comparison between potential and travel cost measures see, for example, Linneker and Spence (1992) and Gutiérrez (2001).

The 'basic' market potential equation takes the following form:

$$\mathrm{Acc}_i = \sum_j \frac{W_j}{c_{ij}^a} \qquad (1)$$

where W_j is a measure of the size or mass of location j (e.g. measured in terms of population or GDP), and c_{ij} is the cost of overcoming the distance between i and j. The exponent a refers to the friction of distance. The larger the value of a, the greater the distinction between nearby and distant destinations. Ideally, it should be estimated from a destination choice model, but adequate disaggregate information is often not available. The value will crucially depend on the type of activity involved. For example, for accessibility to jobs, education, or hospitals, shorter average trip length will imply higher values of a, while for industrial activity patterns lower values are used to reflect their larger interaction space. In national and international studies of accessibility to economic activity a has frequently been assumed to be equal to one (as, for example, in Bruinsma and Rietveld, 1993; Gutiérrez, 2001).

The measure reflects the size of the potential market area a given location has access to after taking into account the cost of overcoming distance. It has been applied in a number of population and GDP weighted exploratory accessibility studies (see, for example, Vickerman et al., 1999; Gutiérrez, 2001; O'Kelly and Horner, 2003), studies of accessibility to public facilities (Haynes et al., 2003), as well as studies analyzing the impacts of transport infrastructure improvements on productivity (Johansson, 1993), employment growth (Linneker and Spence, 1996; Bruinsma and Rietveld, 1993), and firm location (Head and Mayer, 2004; Holl, 2004a,b).

Traditionally there have been no strong theoretical underpinnings for the market potential accessibility measure. However, the concept is appealing because it relates to the natural phenomenon that the volume of interactions such as, for example, trade between locations is lower the further apart they are. Recently, Fujita et al. (1999) show how market potential can be given a formal spatial modelling interpretation. In addition, the expression in terms of a negative exponential function, which is empirically similar, allows for a theoretical justification based on behavioural principles of stochastic utility maximisation (Geertman and Ritsema Van Eck, 1995).

2.4. Space and time in accessibility measures

Accessibility indicators express the location of a spatial unit in relation to the road network in the case of network access and in relation to the road network and all other locations in the destination set in the case of travel cost measures and market potential accessibility. To derive meaningful indicators, the spatial dimension, i.e. the level of spatial disaggregation must be 'fine' enough. However, in national and international accessibility studies, accessibility indicators have usually been calculated for relatively large regions based on the distances between the centroids. Even at NUTS level 3 this can be problematic. In the case of Spain, several NUTS 3 regions are still fairly large, e.g. almost half of the NUTS 3 regions are bigger than 10000 km^2. In these cases, connectivity to the inter-regional transport networks varies considerably between the main cities and the rest of the regions. This study, therefore, calculates accessibility measures on the basis of the much smaller municipalities (NUTS V). This allows the calculation of a more continuous accessibility surface and has the advantage of reducing the problem of intra-zonal travel.

Alternatively, Geertman and Ritsema Van Eck (1995) in a local study of the Randstad area and Spieckermann and Wegener (1996), Schürmann et al. (1997) and Vickerman et al. (1999) in European wide analyses use grid systems with cells of regular size such as 10×10 km as in the case of the latter three studies. This also produces a very detailed accessibility surface independent of variations in the size of the spatial units. A grid system has the advantage that demarcation by administrative boundaries can be avoided, but the disadvantage of this approach is that socio-economic data is only available for administrative units. Thus, synthetic raster data has to be generated and that requires assumptions regarding the intra-regional spatial distribution. Moreover, findings based on administrative units can be more directly related to the policy level.

In empirical research the spatial scale of analysis adopted is crucial as the importance of transport is likely to differ at different scales (Weisbrod and Treyz, 1998). The literature of firm location, for example, suggests that among industrialised countries where transport networks are well developed new transport infrastructure has a relatively stronger influence as location factor at the intra-regional and local level than at broader levels

(Holl, 2006). This reinforces the need for accessibility information at a detailed geographical level.

To assess the spatial distribution of accessibility gains from transport infrastructure investment programmes, it is also important to have time series information. This requires accessibility measures that are based on the evolution of the actual transport networks rather than on great circles. Combes and Lafourcade (2005) show that in cross-section analyses such measures show a high correlation but great circle measures cannot capture transport improvements as variations over time are only due to changes in the masses of the destinations.

3. Network building and accessibility calculation

Using GIS, the Spanish road network is established for the period from 1980 to 2000. The historical evolution is based on detailed information obtained from the Ministry of Public Works regarding the opening of new motorway segments. This information has been combined with information from the annual official roadmaps published by the Ministry of Public Works. For each road segment in the GIS data base, the associated tabular data contains the type of road link, its lengths, and national road identifier number. Each motorway link segment furthermore has been assigned the year it was opened to traffic.

Fig. 1 shows the evolution of the Spanish road network over the last two decades. Part (a) shows the network as in 1980. The motorway network was basically non-existent. Motorways were limited in and around the major urban agglomerations and there were some motorway connections in the north-eastern part of the country. However, Madrid, the capital, was not linked by motorways to any of the other economic centres of the country. Part (b) of Fig. 1 shows the network as of the year 2000. The principal radial motorway network has been largely completed linking all autonomous communities and the major province capitals.

The remainder of this section illustrates the changes in terms of intra-regional and inter-regional accessibility using network access and market potential accessibility. The two measures provide complementary information about the transport system. Access to the higher order road network reflects intra-regional differences in travel opportunities. For measures reflecting the opportunities to the national main markets the fact that places at greater distance are visited less frequently is necessary to be taken into account. Therefore, to measure inter-regional accessibility potential measures are used. Firstly, this avoids arbitrarily selecting the main markets in advance as would be necessary with the travel time measure. Secondly, the travel time measure is likely to give a misleading picture in the case of inter-regional or large-scale economic accessibility. Take for example two main markets at a distance of several hundreds of kilometres. This could be Madrid and Barcelona in Spain. Locations in between those two main markets would assume similar values as those close to one of the main markets. Clearly, where transport costs are important, this does not give a realistic picture of the economic landscape.

3.1. Access to the inter-regional motorway network

Access to the inter-regional motorway network is computed as the straight air-line distance from each of the 7942 Spanish mainland municipalities' centroids to the nearest inter-regional motorway. This is a corridor measure as in Gutiérrez and Urbano (1996).

Table 1 highlights that there have been very large differences in terms of distance to the higher order road transport networks in Spain. Before the road construction programmes were launched, the average straight airline distance to an inter-regional motorway was over 60 km with a maximum value of 262 km. After the massive road building, the average distance was reduced to slightly over 20 km and the maximum distance was reduced to about 115 km. The absolute gap between those locations with close proximity to motorways and those furthest away has narrowed considerable.

In the lower part of Table 1, the evolution of some inequality indices is shown. They describe the distribution of access across areas by combining values for individual areas into one measure of spatial concentration. As indicated by the increase in all three inequality measures, the spatial distribution of access to the motorway network among Spanish municipalities has become more polarized.

Table 2 presents some population and area based descriptive statistics and their evolution over the study period. In 1980, only 8.9% of the peninsular territory fell within a 10 km distance to an inter-regional motorway network. Broadening the corridors to a distance of 40 km as in Gutiérrez and Urbano (1996) increases this figure to 28.5%. By the year 2000, the territory covered by corridors of 10 km and 40 km width was 31.4% and 76% respectively. In terms of population, in 1980, 50.6 % of the peninsular population lived in 10 km proximity to inter-regional motorways and 64.3% in a distance of 40 km. The motorway building programme of the 1980s and 1990s extended the network to cover 79.4% of population in the 10 km corridors and 95.4% in the 40 km corridors.

The population based percentages are much higher than the area based ones. This makes sense, because roads are precisely built to connect population centres and, thus, larger places tend to fall within shorter distances. For the same reason, population weighted average distances to the nearest inter-regional motorway are considerably lower than the arithmetic averages. In the lower part of Table 2, the number of new kilometres of motorway network constructed in each sub-period is related to the number of new population covered by the respective corridor extensions. This relationship varies considerably across the four sub-periods. The highest impact is observed for the second half of the eighties when, on average, one new kilometre

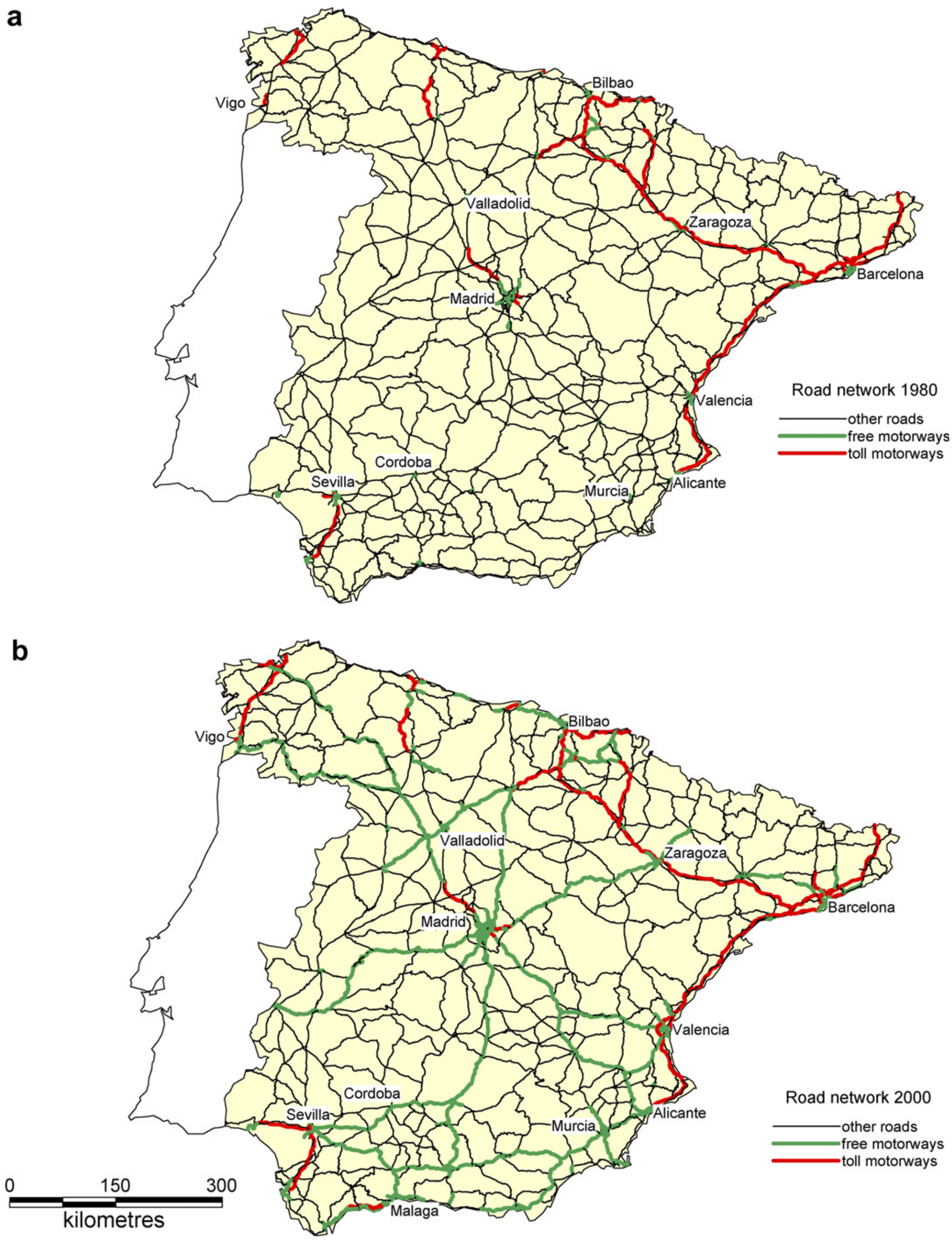

Fig. 1. The Spanish road network in (a) 1980; (b) 2000.

reached about 2700 new people at 10 km distance and about 3500 new people by extending the 40 km corridor. During this period the first major motorway segments linking to important urban centres opened to traffic.

3.2. Market potential accessibility

Next a measure of market potential is constructed. In the absence of detailed local data on expenditure or consumption patterns to represent the size of market demand in different locations, population represents a reasonable proxy:

$$\mathrm{ACC}_i = \sum_{j \in L_{438}} \frac{\mathrm{POP}_j}{c_{ij}} \tag{2}$$

As in Holl (2004a), POP_j is the population of the municipalities in the destination set L_{438} defined as all municipalities with more than 10000 inhabitants, totalling 438 municipalities. This covers over 75% of the total Spanish peninsular population. c_{ij} is the distance between munici-

Table 1
Distance to the nearest interregional motorway (in km)

	1980	1985	1990	1995	2000
Summary statistics					
Mean	64.5	64.2	36.6	28.1	22.5
Std. dev	54.7	54.6	32.5	26.4	21.4
Min	0	0	0	0	0
Max	261.8	261.8	165.6	147.3	115.5
Inequality indices					
Coefficient of variation	0.8488	0.8508	0.8883	0.9403	0.9498
Gini	0.4607	0.4615	0.4808	0.5006	0.5044
Theil	0.3561	0.3574	0.3850	0.4192	0.4253

Table 2
Population and area based network access statistics

	1980	1985	1990	1995	2000
Population weighted mean	43.0	43.2	18.3	10.9	7.8
% of total peninsular population					
Within 10 km corridors	50.6	50.9	65.2	73.7	79.4
Within 40 km corridors	64.3	64.1	82.6	91.5	95.4
% of total peninsular area					
Within 10 km corridors	8.9	9.0	18.3	25.9	31.4
Within 40 km corridors	28.5	28.7	53.5	66.9	76.0

	1980–85	1985–90	1990–95	1995–2000
Length of new network (km)	517	1985	2527	2087
New population within 10 km/km	894.2	2734.6	1403.6	1260.4
New population within 40 km/km	794.5	3525.5	1518.3	978.6

pality i and j measured in travel time where $c_{ij} = 1$ for all municipalities that are less than half an hour travel time apart.[2]

Fig. 2(a) displays the map of market potential accessibility in Spain for 1980. A striking feature is the wide disparity in accessibility levels ranging from just 45% to over 200% of the national average. The major urban areas, Madrid, Barcelona, Valencia and their surrounding areas, stand out with the highest accessibility. High levels of accessibility in the Bilbao and to some extent Seville area are also visible. As would be expected, accessibility decreases from the major cities to the rural areas, but there are also high-accessibility corridors along the few motorway links that existed at the beginning of the eighties in Spain, notably, the Valle de Ebro corridor in the north-east and the Mediterranean coast corridor. Fig. 2(b) shows the accessibility map for 2000. Overall a very similar pattern of accessibility distribution is visible with the same high-accessibility areas standing out.

Fig. 3.1(a) displays the absolute changes in market potential accessibility over the period from 1980 to 1994. This covers the first road building programme. There are gains in all municipalities, although to a varying degree. The south (Andalucía) has clearly benefited to a greater degree from the first road building programme in terms of accessibility and so have the municipalities along the motorway corridors that have been built. Madrid with its already high accessibility has further gained. Little gains have been experienced in the northern part of the country.

In relative terms the picture is similar, though there are two distinct features worth mentioning (Fig. 3.1(b)). First, Madrid gains little in relative terms given that it had already a very high accessibility. Second, Galicia, in the north-western corner of the country, with one of the lowest accessibility levels due to its peripheral position showed little gains in absolute terms, but is in a somewhat better position in terms of relative gains. The area that has gained the least in terms of national accessibility from the first major road programme is the north-east (Catalonia and parts of the Basque Country, Navarra and Rioja).

Fig. 3.2(a) and (b) displays the absolute and relative changes in accessibility that have taken place over the second half of the nineties. The most marked improvements have taken place in the more peripheral areas of the country, particularly in Galicia and in the south-east of the country along the Mediterranean coast (Almeria, Murcia and Alicante).

The maps suggest that although the overall pattern of market potential accessibility has not changed substantially, there have been marked differences in terms of gains. Some of the greatest accessibility increases due to the road building programmes in Spain have been experienced in the more peripheral areas indicating a process of narrowing of spatial inequality in terms of potential market accessibility. The evolution of the inequality indices in Table 3 also indicates that the motorway building programmes in Spain have led to a slightly more homogenous spatial distribution of market potential accessibility.

This section has illustrated how changes in transport infrastructure lead to changes in accessibility. Accessibility is a means to an end, such as for example more balanced spatial development. The empirical modelling of the link between accessibility and economic development is, however, beyond the scope of this paper. The next section reviews the literature on ways in which accessibility changes stemming from transport infrastructure improvements can impact on regional development and affect the spatial distribution of economic activity.

[2] Travel times are based on travel speeds of 120 km/h for motorways and dual-carriageway roads, and 90 km/h for other roads. Network access is calculated as the straight air-line distances from each municipality centroid to the nearest road link for access to the secondary and third order road network assuming that access is basically continuous. Where the nearest road link is a motorway, the distance is measured to the nearest access node. In both cases the travel time used to approximate the straight air-line distance is 30 km/h. Finally, as in most accessibility studies, a is assumed to equal 1.

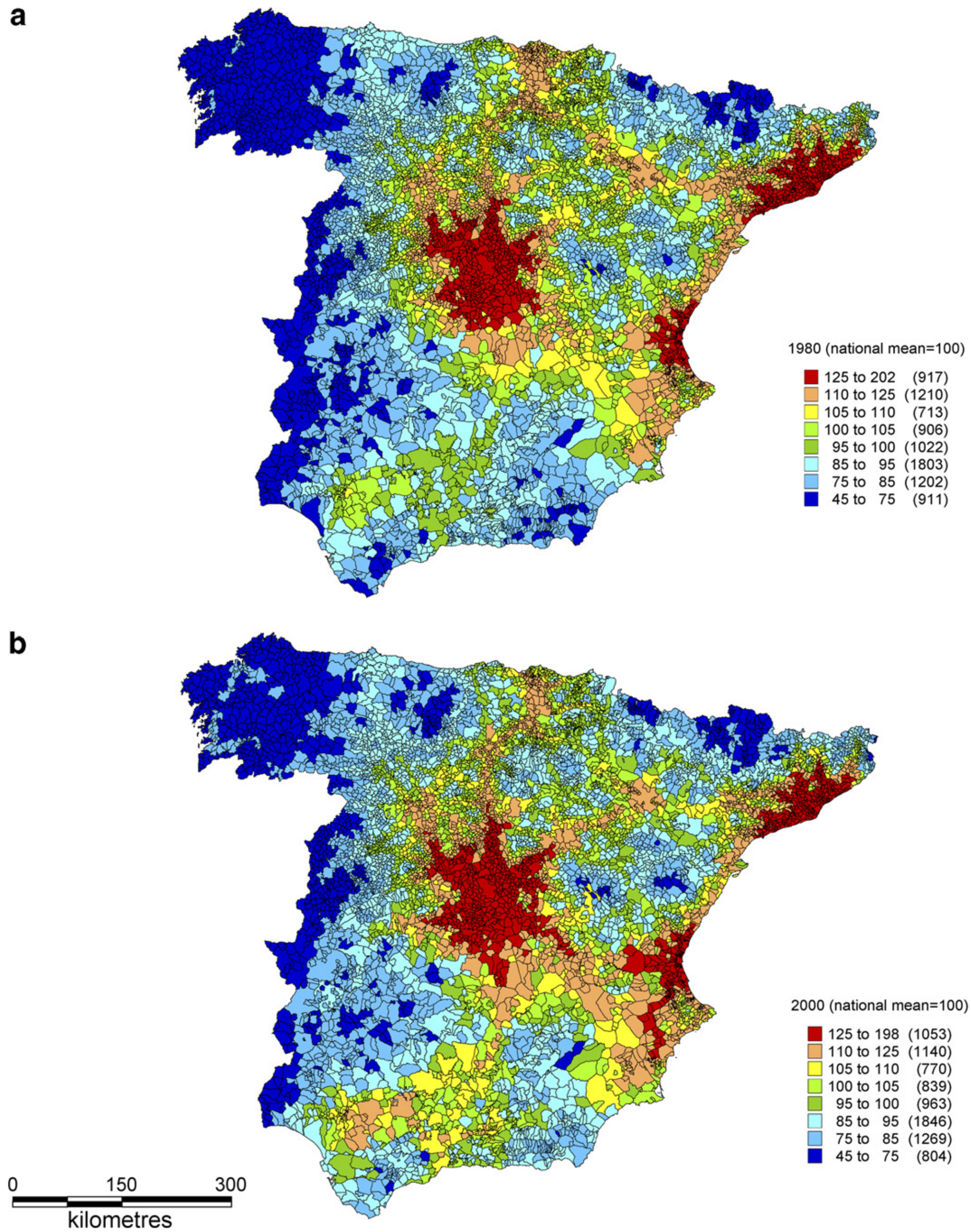

Fig. 2. Potential population accessibility: (a) 1980; (b) 2000.

4. Transport infrastructure and accessibility improvements, regional development, and the spatial distribution of economic activity

Economic theories attribute an important role to transport infrastructure for regional development. It provides regions with better access to the locations of input materials and markets. This can affect firms' competitiveness through productivity and consequently output levels, but it will also influence where firms tend to locate and the resulting trade patterns between regions.

A wide range of studies have analysed the relationship between regions' infrastructure endowment and productivity and output. Transport infrastructure constitutes a major part of infrastructure capital, though only few studies explicitly estimate the effect of transport infrastructure or roads in particular (see, for example, Aschauer, 1989; Garcia-Milà and McGuire, 1992; Fernald, 1999). Aschauer (1989) uses aggregate time series data for the USA for the period 1949–1985 in a production function approach and estimates a very large output elasticity of public capital of 0.39. Disaggregating total US public capital, Aschauer concludes that transport infrastructure and energy and water infrastructure have the strongest impact. The study generated a series of other contributions in this field. Later US studies found much lower but still positive and

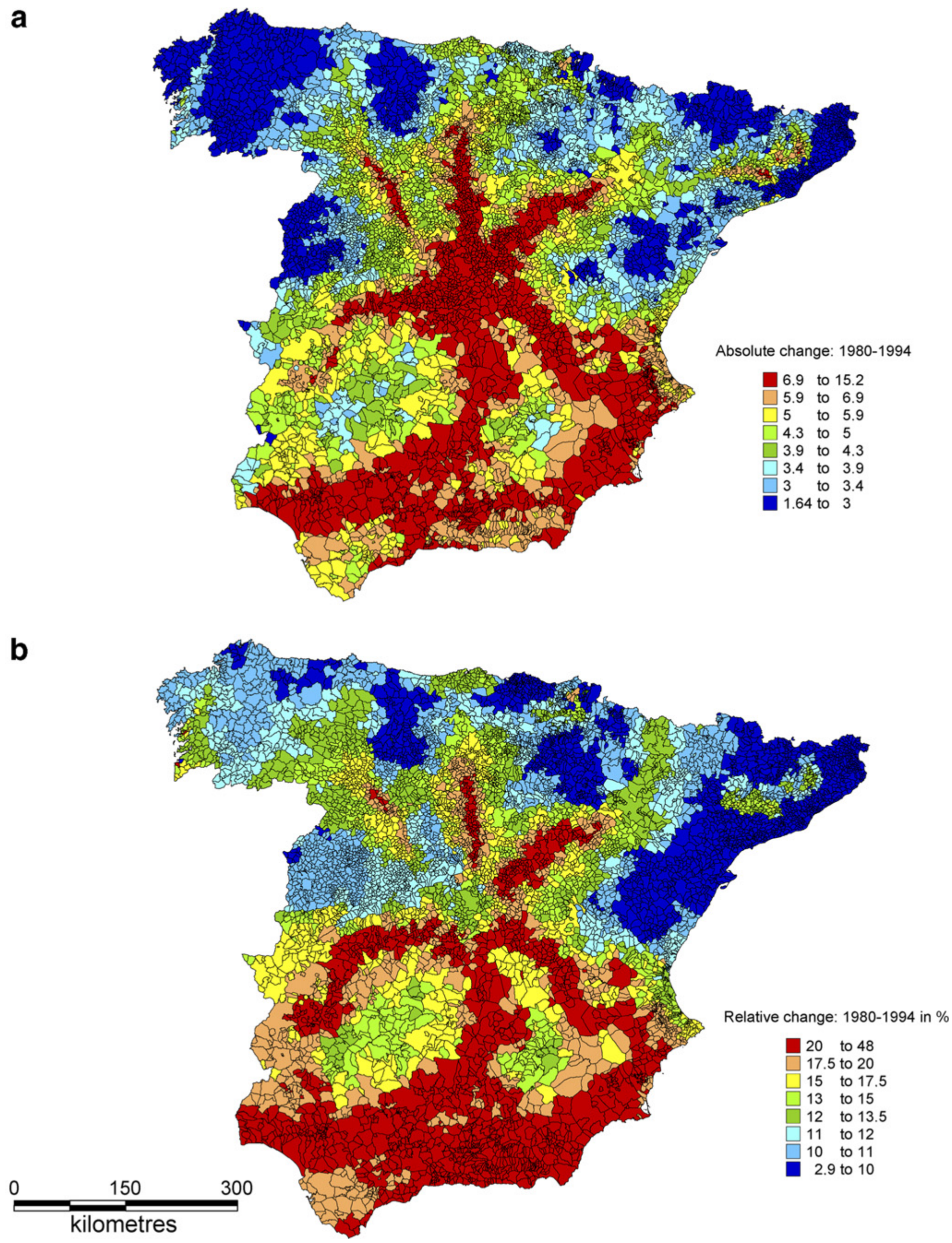

Fig. 3.1. Change in potential population accessibility: 1980–1994. (a) Absolute change; (b) relative change.

significant output responses, while others have been much more sceptical (for a review of this literature, see, Gramlich, 1994). Fernald (1999) particularly focuses on roads and argues that road infrastructure investment is associated with larger productivity growth in industries that use roads more intensively. He concludes that the large-scale road building of the 1950s and 1960s in the US raised the level of productivity, but did not lead to a continuing growth path in productivity. There are also a number of studies for Spain. Mas et al. (1996, 1998) and Flores de Frutos et al. (1998), for example, provide estimates of public capital in Spain. Mas et al. (1996) estimate a regional production function for the Spanish autonomous communities between 1964 and 1991. They find a significant positive output elasticity of 0.07, with similar results in Mas et al. (1998). Flores de Frutos et al. (1998) use a dynamic multivariate framework and also find a positive long-term effect of public investment on private output.

There are important issues regarding the redistributional effect of transport infrastructure investment. Aggregate studies are likely to capture a mix of two different relationships. Infrastructure investment is place-specific and consequently there might be output increases in some regions, whereas output decreases in other regions. Hence, aggregate results are difficult to interpret. Boarnet (1998) argues for Californian counties that road infrastructure

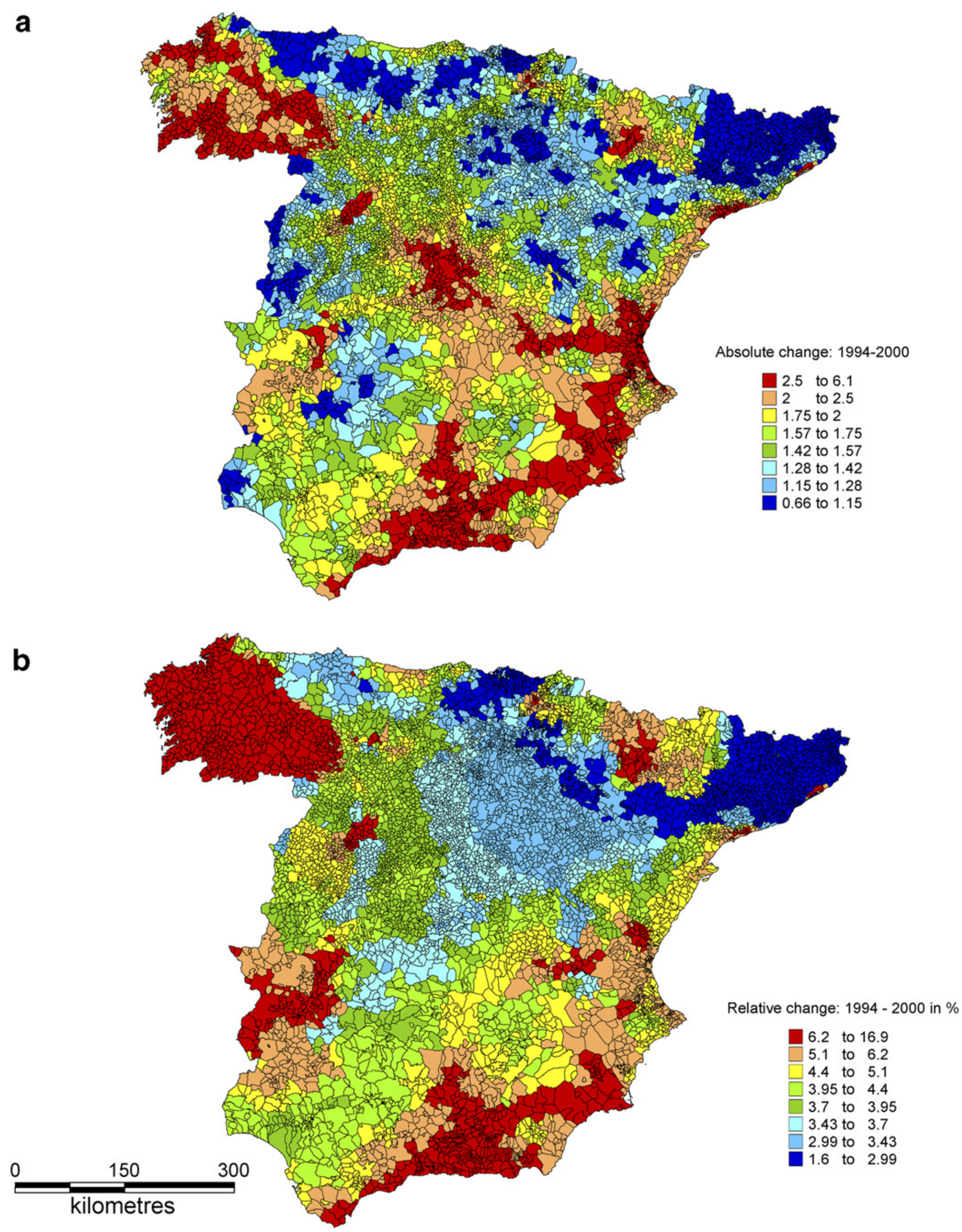

Fig. 3.2. Change in potential population accessibility: 1994–2000. (a) Absolute change; (b) relative change.

investment has been associated with higher output within the same county, but lower output in counties that compete for mobile factors. On the other hand, he finds positive spillover effects across contiguous counties when the degree of connectivity provided by the highway network is taken into account. For Spanish regions, positive spillover effects have been found by Mas et al. (1996). Pereira and Roca-Sagalés (2003) more recently also conclude for Spain that aggregate effects are due in almost equal parts to direct and spillover effects of public capital.

Table 3
Variation in potential population accessibility indices

	1980	1985	1990	1995	2000
Summary statistics					
Mean	35.5	36.3	38.5	40.6	42.2
Std. dev	8.5	8.6	9.1	9.4	9.6
Min	16.1	16.6	17.3	18.0	19.2
Max	71.4	72.9	77.2	80.6	83.2
Inequality indices					
Coefficient of variation	0.2391	0.2367	0.2371	0.2325	0.2282
Gini	0.1236	0.1224	0.1236	0.1226	0.1202
Theil	0.0265	0.2596	0.0262	0.0254	0.0244

In modelling the link between infrastructure and economic growth the above studies have used capital stock data. By reducing transport costs, transport infrastructure improvements principally change accessibility to output markets and inputs suppliers. Accessibility measures provide a way to quantify the effect of transport infrastructure improvements through the links to output and input markets. They have the advantage over infrastructure stock measures of taking into account the network character of transport infrastructure. In this sense, the concept of accessibility more closely relates to the services provided by transport infrastructure of reducing the friction of distance and bringing economic agents together. A further drawback of infrastructure stock measures is that they are generally only available for fairly aggregated spatial units and therefore not suitable for analysis of intra-regional impacts or impacts at the micro-level.

Based on motorway network access at the municipality level, Holl (2004a), for example, shows that one effect of new motorways constructed in Spain has been a densification of firms in the vicinity of the projects, with evidence that also suggests negative spillovers at the intra-regional level. The new infrastructure has made locations in its vicinity more attractive for manufacturing firm location, but reduced the attractiveness of location beyond the first 10 km. Further recent evidence of the role of accessibility for firm location at the geographically detailed level is provided in Coughlin and Segev (2000) for the US, and Guimarães et al. (2000) and Holl (2004b) for Portugal. These studies have used network access, travel time measures, and market potential and network measures, respectively.

Regarding the spatial distribution of economic activity, there have been important theoretical contributions within the field of new economic geography. Such models point to a complex mechanism by which transport infrastructure affects the spatial distribution of firms. Puga (2002) provides a recent review of the main mechanisms at work. Fujita and Mori (2005) specifically focus on the role of transport cost reductions. As roads are built in two directions it is a priori not clear whether core or peripheral locations will gain more from accessibility improvements. Market-size and linkage effects foster geographical concentration. Consumers prefer to concentrate at locations where a wider variety of products is available. Increasing returns in the production of differentiated goods makes firms concentrate where they find a large number of consumers as well as a sufficiently large labour pool. At the same time, forward and backward linkages of vertically linked industries creates greater local demand and transport cost savings on intermediate inputs (Venables, 1996). Working against such concentration are local demand of dispersed immobile consumers, price differences in immobile factors, and competition. Reductions in transport costs change the balance between these forces and can therefore have opposing effects in different regions. The models predict a reorganisation of economic activity that follows an inverted U-shaped relationship between transport costs and agglomeration. If transport costs are high, firms find it profitable to locate dispersed to supply markets locally and take advantage of lower costs of immobile factors and lower competition than in agglomerations. With reductions in transport costs firms can serve markets from a greater distance. This allows them to concentrate in larger markets and take advantage of agglomeration economies. However, as transport costs continue to fall, proximity to other firms becomes less important, and peripheral regions with their lower prices for local factors and lower competition may gain again in attractiveness. Hence, the new economic geography literature predicts a weakening of agglomeration forces with decreases in transport costs beyond a certain threshold level (Fujita et al., 1999; Puga, 2002; Fujita and Mori, 2005).

Recent new economic geography models highlight the relevance of the market potential accessibility concept. In empirical studies, Hanson (2005) examines the relation between market potential and wages across US counties. Hanson considered the traditional Harris-type accessibility measure, together with a functional form that is more closely related to the new economic geography theoretical models. In both specifications, he found significant positive correlations. Redding and Venables (2004) report evidence that market and supply accessibility are significant determinants of cross country variations in per capita income. Based on French data, Combes and Lafourcade (2004) present simulations that show that transport cost reductions lead to lower concentration of employment and production at the national scale but widen intra-regional disparities. With high transport costs, profits are monotonically decreasing from the core area of the Île-de-France employment area towards the periphery. As transport costs are reduced, further high-profit areas emerge, however, with profits locally falling more steeply as one moves further away from the centres of these high-profit areas.

Although not based within the framework of new economic geography, other empirical evidence on the impact of transport improvements on the spatial distribution of economic activity has been reported in a number of studies. Haughwout (1999) estimates reduced form employment growth equations for US counties controlling for growth in highway capital stock. His results suggest that infrastructure investment tends to disperse growth away from high density metropolitan areas to less dense metropolitan area counties. Linneker and Spence (1996) study the relationship between regional employment and accessibility changes due to the construction of the M25 London orbital motorway. Based on market potential accessibility measures, their findings highlight that transport improvements can have varying impacts. In estimations using the level of accessibility, employment growth was found to be highest in areas with low accessibility. Areas of high accessibility have shown losses in employment, suggesting, as the authors argue, that the most accessible places are also the most costly places and therefore may not be the best places for business expansions. However, in addition to this negative relationship, changes in the level of accessibility have been positively related to employment growth. The M25 construction has allowed a decentralisation of employment, especially to those areas that have experienced high gains in accessibility. Very likely those are the areas along transport corridors. Linneker and Spence (1996) results differ form the earlier UK studies of Dodgson (1974) and Botham (1980) that suggested that road building during the 1960s and 1970s has had a centralising effect by favouring employment in the most accessible areas.

The concept of accessibility has recently received renewed attention in empirical studies concerned with transport infrastructure impacts and the spatial distribution of economic activity. Economic activity takes place in space and the analysis of many empirical questions in these fields requires models that are fine scale and spatially explicit. The concept of accessibility relates directly to space and networks and can help to answer questions concerning spatial phenomena.

Accessibility measures are also increasingly used in planning, policy analysis and project evaluation, but to capture total benefits from transport improvements requires a better understanding of how accessibility improvements translate into economic impacts. By large, there is agreement that positive effects exist but the above studies also point to complex mechanisms by which transport infrastructure affects the development in particular regions.

5. Conclusion

Over the last 20 years, Spain has developed an ambitious motorway building programme. This has endowed the country with important transport infrastructure that links the major cities of the country and also provides improved access to European markets. In this paper, the resulting accessibility changes have been analysed using network access and potential market accessibility measures. Accessibility levels have improved all over the country, but the size and distribution of accessibility gains has been uneven. In terms of motorway network access, the absolute gap has narrowed considerably between those locations in close proximity and those furthest away, but in relative terms the distribution has become more polarised. In terms of accessibility to market centres, disparities slightly declined, as some of the largest gains in market potential accessibility have been experienced by more peripheral regions.

Both the theoretical and empirical literature shows that investment in transportation infrastructure and the resulting changes in accessibility patterns affect regional development and the spatial distribution of economic activities. Transport improvements have the potential to disperse economic activity, particularly activities with lower transport costs. This thus can provide a more even pattern of development across regions. But empirical evidence also suggests that intra-regionally, benefits of transport improvements tend to be concentrated near the infrastructure projects. This is consistent with views that new transport infrastructure reduces inter-regional disparities but can widen intra-regional ones depending on access to high quality transport infrastructure such as motorways.

The literature highlights that the relationship between transport improvements and economic development is complex and depends on a multitude of factors. Thus, a priori, economic development cannot be taken for granted as a result of accessibility improvements. More research in this area is needed. As microeconomic data is becoming increasingly available, combining such data with geographically referenced data at the fine grained spatial level is a promising area for future research in order to gain a better understanding of the complex mechanisms that translate accessibility gains into economic benefits.

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