# 3. Population decline and accessibility in the Portuguese interior

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## 3.1 INTRODUCTION

Improvements in accessibility increase the attractiveness of a place, as they increase the number of opportunities that can be reached by its population (Wachs and Kumagai 1977). While this idea is generally valid in the case of urban areas, in rural contexts improvements in the ease of access of distant places can also contribute to population decline, as they may induce people to move to those other places and then travel regularly to their home towns to visit friends and family.

More broadly, the role of transport as a pull or push factor for migration in rural areas depends on the type of accessibility it improves. It is important to identify the type of destinations that are made accessible. For example, different populations place a different value on access to national, regional or local centres, and on access to jobs or services (Farrington and Farrington 2005). The mode of transport is also relevant. While improvements in private transport accessibility are directly linked with the reduction of travel times on the road network, improvements in public transport accessibility also depend on the suitability of services and schedules and on levels of access to transport nodes such as train or bus stations (Ochojna and Brownlee 1977; Nutley 1985; Martin et al. 2002; Martin et al. 2008). Empirical research can only capture the relationships between accessibility and population dynamics if the measures of accessibility used reflect the changes to the options that are considered as feasible by the populations.

The links between accessibility and population dynamics may also differ from prior expectations in the cases where accessibility deteriorates (for example, when public transport services are withdrawn). There is only a small amount of evidence on the effects of railway line closures on the communities living in the affected areas (Whitelegg 1987; Taylor 2006). Very few of the available studies investigate the effect on population change. In order to assess the social relevance of line closures, more research is needed on their impacts on accessibility and on population change. However, this assessment is not straightforward, as there are different possibilities for evaluating levels of access to railway services and the lost potential in terms of diversity of travel destinations or severed access to opportunities in those destinations.

The objective of this chapter is to assess the influence of changes in accessibility on the population decline in the Portuguese countryside in the two last decades. The analysis compares two types of accessibility changes: those related to the investment in the road network and those related to the disinvestment in the railway network. The relationships are controlled for changes in local (non-motorized) accessibility and control variables measuring characteristics of the population and of the natural and social environment.

The chapter also addresses methodological issues related to the selection and measurement of indicators of accessibility. The analysis compares the effects of alternative indicators, measuring access to the motorway and railway networks, the number of places that can be accessed, and the number of opportunities existing in those places. The construction of the indicators also incorporate detail regarding different frequencies (daily or weekly), departure and arrival times (morning, afternoon or evening) and travel time thresholds for trips to work. The analysis of rail trips takes into account the availability of services for return trips, connection times between different services, and public transport options and times for accessing stations.

The chapter proceeds as follows. The next section briefly reviews the literature on the multiple relationships between accessibility and population change and on the way those relationships depend on the specification of accessibility indicators. Section 3.3 is an overview of the population decline in the Portuguese interior in the last 20 years and of the large-scale investment in the motorway network and disinvestment in the rail network occurring in that period. The variables and model specifications are presented in section 3.4. Section 3.5 presents the findings of these models, and section 3.6 concludes the chapter with some reflections on the policy and research implications of this study.

## 3.2 TRANSPORT AND RURAL POPULATION CHANGE

There is a large amount of empirical evidence on the relationships between accessibility and population change at the local level (Voss and Chi 2006; Kotavaara et al. 2011; Mojica and Martí-Henneberg 2011; Chi 2010, 2012; Koopmans et al. 2012; Ji et al. 2014). A wide diversity of impacts has been identified, usually specific to the geographic context in which they were found. The effects of accessibility on population change in rural areas tend to be different from those in suburban and urban areas (Chi 2010, 2012). The populations in these three types of areas differ in terms of accessibility needs as they also differ in terms of age, marital status, employment status and sector of employment. In addition, factors such as geographic isolation and dependence in relation to local and regional centres are more relevant in rural areas than in urban and suburban areas, where the geographic distribution of population and employment is less concentrated. On the other hand, the negative effects of the transport system (such as congestion and pollution) have a higher influence on the patterns of residence location in urban and suburban areas than in rural areas.

In general, improvements in accessibility have a positive impact on population change, although it is not always easy to disentangle the chain of causes and effects leading to that impact. Usually, the relationship between accessibility and population change is mediated by economic factors (Button 1995; Rietveld and Bruinsma 1998). Accessibility attracts investment and improves local economic conditions and job prospects, which in turn lead to population increase. In contrast, geographic isolation tends to be linked with out-migration, sometimes independently of economic or employment factors (McNabb 1979).

The general hypothesis above applies to different types of investment in transport infrastructure such as road (Voss and Chi 2006) and rail networks (Mojica and Martí-Henneberg 2011), which tend to be positively related to rural population change, contributing to population growth in the areas served and, in some cases, to the depopulation of the areas that are not served. Studies including the two types of investment in the same empirical model have also found that they have independent effects on population change (Kotavaara et al. 2011).

However, accessibility may also have a negative effect on population change as it allows people to migrate to the areas that are made more accessible, a phenomenon usually identified as one of the negative spillovers from transport infrastructure (Boarnet 1998). The reduction of travel times induces people to relocate to areas with better employment prospects, while maintaining social relationships in their home towns through regular visits. A negative relationship between accessibility has been found, for example, in the study of Vaturi et al. (2011), who found that in suburban areas within reach of a large city, access to railway contributes to a negative migration balance.

A case with far less empirical evidence is that of the disinvestment in the transport infrastructure. A few studies of railway closures have shown that the withdrawal of passenger services has effects on economic activity and social structures in rural areas (Whitelegg 1987; Taylor 2006). However, railway closures may not have a negative effect on either economic activity or population change, when the withdrawal of services is combined with the positive impacts of other forms of economic rationalization (Parolin et al. 1993).

The empirical analysis of the links between changes in accessibility and population dynamics also depends on the type of accessibility that is measured. Different conclusions about spatial variations in accessibility can be reached for different measures (Vandenbulcke et al. 2009). Moreover, each measure is linked to a specific normative aspect (Páez et al. 2012). Parameters that are not obtained through the modelling of people's actual behaviour (which is often the case of travel time thresholds) reflect a certain judgement about their well-being. While the use of a diversity of accessibility measures is welcomed, in practice policy-makers tend to use a small number of relatively simple indicators. This is because complex measures are not always easy to make operational (Geurs and van Wee 2004).

The set of indicators found in studies relating accessibility to population dynamics is large. Some studies provide general measures of the travel possibilities available at one place, such as the density of roads (Voss and Chi 2006), or the presence of a station in the vicinity of that place (Koopmans et al. 2012). Other studies focus on the separation between a place and specific destinations, measured by the distance or travel time to centres (Millward 2005), the distance or travel time to the nearest access point to the private or public transport networks (Kotavaara et al. 2011), and maximum time thresholds to travel destinations (Ribeiro et al. 2010). Potential accessibility measures have also been found to have a good explanatory power in the modelling of population density (Song 1996). These measures assume that accessibility depends positively on the number of opportunities in each destination and negatively on travel time. While the range of possible indicators is large, it should be noted that they measure dimensions of accessibility that are at least partially independent from each other. Empirical studies can then include several measures of accessibility in the same models.

In the definition of a suitable indicator, options must be taken, however, regarding the nature of the destinations that people need to access. Models relating population change with potential accessibility measures tend to use population size as an indicator of the attractiveness of that destination. However, the distribution of the population may not be related tothe distribution of workplaces and the services and facilities people need to access. In the case of ageing rural populations, the spatial distribution of health facilities is a special case of concern (Escalona-Orcao and Díez-Cornago 2007).

Recent advances in accessibility studies have also shown the importance of time constraints in the definition of accessibility and the need to consider aspects such as the set of available transport options, trip chaining and opening times of facilities (Weber and Kwan 2003; Dong et al. 2006). This is especially relevant in the case of public transport accessibility, which depends to a large extent on factors such as departure times (Ochojna and Brownlee 1977) and frequency of services (Nutley 1985). An examination of the availability and frequency of connections between different places, and of bus access to rail or coach stations, may reveal that services fail to meet the accessibility needs of the populations. The withdrawal of these services may then have little impact on population change, as they may have ceased to be considered as a viable transport alternative.

## 3.3 POPULATION DECLINE, ROAD INVESTMENT AND RAILWAY DISINVESTMENT IN PORTUGAL

The spatial patterns of population change in Portugal reflect the traditional divide between the economically dynamic coastal strips and the lagging regions of the interior. The overall Portuguese population has remained stable over the last decades, at around 10 million. However, Figure 3.1 shows that the population declined throughout most of the interior and grew (or decreased less) in the coastal areas. In addition, the population in the areas with highest decline in the 1991–2001 period continued to decrease during the 2001–2011 period. The black line in Figure 3.1 shows the delimitation of the study area of this chapter. In this area, there are only a few places where the population increased in the periods of concern, in most cases corresponding to municipal capitals.

The two last decades have also seen large-scale investment in the road infrastructure, and especially in the motorway network (left side of Figure 3.2). During the 1990s, this investment was facilitated by the relatively high economic growth and influx of funds from the European Union. However, the expansion of the network accelerated during the 2000s, despite the deterioration of macroeconomic conditions. Some of the new motorways have duplicated the capacity that already existed in the main central coast corridor and others have extended the service to all the regional centres in the interior. As a result of this massive investment, the motorway density in Portugal is now almost double the average density in the European Union.

In contrast, public transport services shrank dramatically during the same periods. The most striking example is the reduction of passenger railway

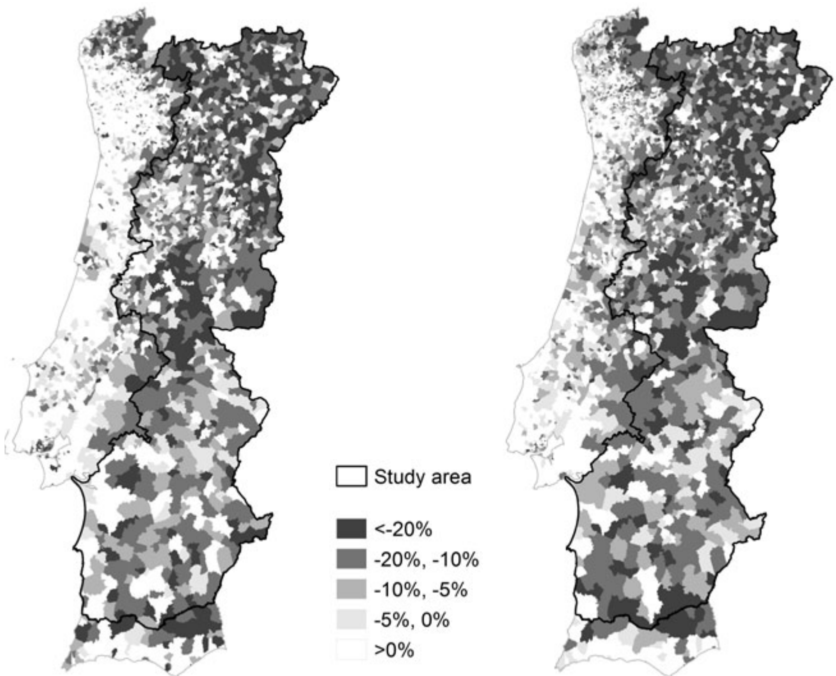


*Figure 3.1 Population change by civil parish (freguesia)*

services, following two waves of line closures, in the periods 1988–92 and 2008–2012 (Figure 3.2). The first wave of closures occurred as a part of the restructuring of the railway sector, which gave priority to the parts of the system with higher economic viability: suburban and intercity transport in the main axes. A large part of the less viable lines (790 km) was closed, mainly in the most isolated parts of the interior: the north-east and southern regions. After a steady reduction of rail services since 1992, the ongoing economic crisis triggered a new wave of line closures, justified as an essential part of the restructuring of the Portuguese public sector. Since 2009, a total of 490 km of railway lines were closed to passenger services, including most of the remaining lines in the north-east and southern regions, while the future of a few other lines remains uncertain. In 2013, only one third of the stations that once served the interior provinces were in operation. Bus replacements for the lines closed, provided by the railway operator, proved to be short-lived.

There is a growing need for the assessment of the links between the three patterns described above. One of the reasons is that there is evidence that the improvement of the road system was insignificant in explaining either

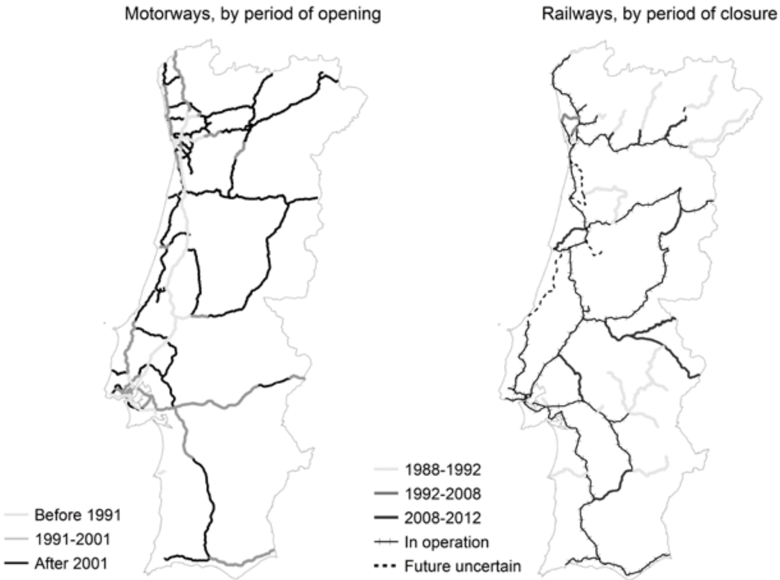


*Figure 3.2 Road investment and railway disinvestment in Portugal*

population or economic dynamics in the period 1991–2001 in part of the regions of concern (Ribeiro et al. 2010). This suggests that the large-scale investment in road accessibility is not achieving the desired objective of convergence between those regions and the more dynamic Portuguese and European regions. At the same time, recent studies have shown that railways have had a positive effect on population growth and economic vitality in small places in Portugal (Mojica and Martí-Henneberg 2011), and that some of the railway lines closed could be economically viable if their service was improved (Tão 2011).

## 3.4 VARIABLES AND MODELS

### 3.4.1 Study Area and Dependent Variables

The study is conducted at the level of the civil parish (*freguesia*), the smallest administrative unit in Portugal. The study area is defined at the level of NUTS 3 regions, and includes the *freguesias* in the regions in continental Portugal where the population decreased at an average of at least 10 per cent in the 2001–2011 period (See Figure 3.1).

The *freguesias* corresponding to the capitals of municipalities are excluded from the analysis, as they have distinct population dynamics, acting as local centres attracting population from the surrounding villages. The study area is then formed by 1640 *freguesias*, with an average of 740, 674 and 602 people in 1991, 2001 and 2011, respectively. Changes in administrative borders were accounted for by assigning to the new *freguesias* and those with changed borders a proportional part of the population of the *freguesias* from which they originated. The analysis refers to a representative point of the main population agglomeration in each *freguesia*; the locations of which are given by data from the Portuguese Geographic Institute (IGP).

The dependent variables are the ratio of the population at the end and beginning of each period. These variables are explained by accessibility measures and control variables (the characteristics of the population and of the natural and social environment). Descriptive statistics for these variables are provided in Table 3.1.

### 3.4.2 Explanatory Variables: Accessibility

The first set of accessibility variables measure geographic isolation, defined in relation to local centres. The first variable is the road network distance to the capital of the municipality to which the *freguesia* belongs. The second is a dummy variable for the *freguesias* located along roads that directly link municipal capitals. A distinction is then made between the opportunities (jobs) located inside each *freguesia*, assumed to be accessible by non-motorized transport (walking or cycling), and those located outside, accessible by motorized transport (car or public transport).

Local accessibility is measured in terms of the change in the number of places that can be accessed by non-motorized modes of transport, considering jobs, businesses and services. These variables can also be interpreted as indicators of local economic vitality. Each *freguesia* is also assigned the number of places in *freguesias* within 15 minutes walking or cycling from its representative point. The numbers of jobs, businesses and services were calculated from a database compiling all the companies registered in each *freguesia*, which is updated every other year by the Portuguese National Statistics Institute (INE). It should be noted that in both periods, the number of jobs, businesses and services are only weakly correlated (correlations of less than 10 per cent between jobs and the other two variables, and of around 35 per cent between businesses and services).

Road and rail accessibility are expressed as changes in the periods concerned. An adjustment is made in the case of the calculation of rail accessibility in order to account for the concentration of the majority of changes

*Table 3.1 Descriptive statistics*

| | Units | 1991–2001 | | 2001–2011 | |
|---|---|---|---|---|---|
| | | Mean | SD | Mean | SD |
| *Population (change)* | relative change | −0.130 | 0.145 | −0.148 | 0.167 |
| *Geographic isolation* | | | | | |
| Distance to municipal capital | km | 9.428 | 5.186 | = | = |
| Along road linking capitals | dummy | 0.004 | 0.004 | = | = |
| *Local accessibility (change)* | | | | | |
| Jobs | change | −0.347 | 0.368 | −0.578 | 0.278 |
| Businesses | change | 0.994 | 1.852 | 0.665 | 1.051 |
| Services | change | 0.563 | 1.589 | 0.403 | 1.022 |
| *Road accessibility (change)* | | | | | |
| Time to motorway | change (minutes) | −81.928 | 30.242 | −37.86 | 34.42 |
| Places accessible (daily) | change | 1.527 | 1.982 | 1.985 | 2.686 |
| Places accessible (weekly) | change | 7.263 | 6.381 | 11.57 | 9.261 |
| Jobs accessible (daily) | 1000 change | 0.00001 | 0.00002 | 19.12 | 25.1 |
| Jobs accessible (weekly) | 1000 change | 0.00041 | 0.00029 | 833.7 | 387.3 |
| *Rail accessibility (change)* | | | | | |
| Time to station | change (minutes) | 8.300 | 16.25 | 1.013 | 7.610 |
| Places accessible (daily) | change | −0.029 | 0.249 | −0.006 | 0.148 |
| Places accessibility (weekly) | change | −0.654 | 3.331 | −0.162 | 1.746 |
| Jobs accessible (daily) | 1000 change | 0.00001 | 0.00024 | 0.049 | 0.781 |
| Jobs accessible (weekly) | 1000 change | 0.00087 | 0.00654 | 3.441 | 22.741 |
| *Natural and social environment* | | | | | |
| Temperature | °C | 13.11 | 2.150 | = | = |
| Slope | % points | 7.172 | 5.768 | = | = |
| Water | prop. agricultural area | 0.009 | 0.046 | = | = |
| Good soil | prop. agricultural area | 0.170 | 0.172 | = | = |
| Forest fires | rel. to forested area | 0.019 | 0.075 | 0.006 | 0.039 |
| Heritage | number of sites | 0.796 | 1.098 | = | = |
| Old businesses | change | 0.325 | 1.117 | 0.407 | 1.126 |
| *Population (initial)* | | | | | |
| Population (initial) | 1000 | 0.046 | 0.061 | 0.043 | 0.068 |
| Young (initial) | prop. population | 0.135 | 0.035 | 0.122 | 0.032 |
| Low-qualified (initial) | prop. adults | 0.732 | 0.075 | 0.398 | 0.066 |
| Graduates (initial) | prop. adults | 0.014 | 0.018 | 0.024 | 0.019 |
| Unemployment (initial) | prop. active | 0.068 | 0.064 | 0.082 | 0.062 |
| Agriculture employment (initial) | prop. employment | 0.433 | 0.219 | 0.279 | 0.188 |

*Notes:* =: same value as in the 1991–2001 period.

in the rail network in two short periods that overlap with the census periods. The changes between 1988 and 1992 are assigned to the period 1991–2001 and the changes between 2008 and 2012 are assigned to the period 2001–2011. This may introduce or reduce distortion in the analysis, depending on the time lag in which population dynamics respond to past or planned changes in rail accessibility. It should be noted that the changes between 2008 and 2012 may affect population growth in the 2001–2008 period because the closure of railway lines was in all cases preceded by a steady reduction in the availability of railway services. The closures in the period 2008–2012 are therefore an indicator of the reduction of services during the preceding years.

Two dimensions of road and rail accessibility are considered: the level of access to the transport network and the options provided by the network. The changes in the access to the network are defined as the changes in the travel times to nearest motorway junction or nearest railway station. These times are measured on the road network and assume that private or public transport is available for accessing rail services, an assumption that is only lifted in the indicators of the options provided by the network, explained below. The road and motorway network and the location of railway stations in 1991, 2001 and 2011 are modelled in a geographic information system based on data from road maps and official rail timetables. The speeds imputed to the road and motorway links were based on speed limits for each type of road and location in each year and on slopes. Dummies are calculated for time thresholds under 15 and 30 minutes. Figure 3.3 shows the proportion of the *freguesias* in the data set under these time thresholds, revealing the convergence between levels of access to motorways and railway stations since 1991.

The changes in the options provided by the transport network are identified as the change in the number of places that are accessible or in the number of opportunities (jobs) available in those places. The distinction between the two sets of variables is made in order to isolate the effect of changes in transport from changes in the number of opportunities in each location.

The set of possible places includes all the *freguesias* in continental Portugal. Time impedance is not considered; that is, places are classified as either accessible or not. While the inclusion of this element would add relevant detail to the measure, it would also require an estimation of parameters measuring the rate of decay of accessibility with travel times, the calibration of which requires unavailable data about population mobility.

Assumptions are placed on the frequency and day of the week that trips are made: individuals commute daily to the workplace, or live near the workplace and return on weekends to the place where they have their

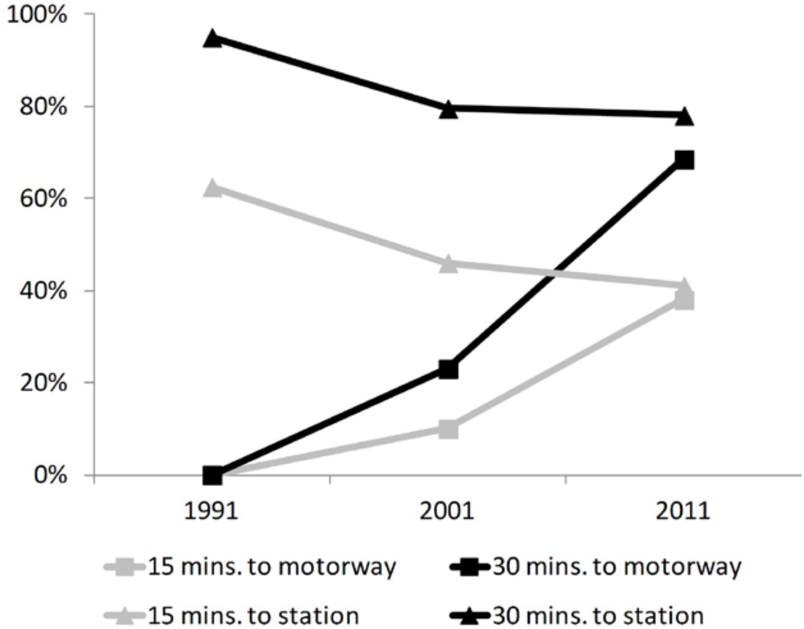


*Figure 3.3 Proportion of freguesias served by the motorway and railway networks*

permanent residence or have family or social ties. A place is defined as accessible on the road network if the private transport travel times to that place are below a given threshold, which depends on the trip frequency. The thresholds are assumed to be one hour for daily trips to work and four hours for weekly trips to work. The identification of places accessible by rail requires further assumptions, related to the level of access to stations, time thresholds for different sections of the trip, and the suitability of existing services in relation to the times of day the trips need to be made.

A database was built in Microsoft Access containing: (1) the travel times by non-motorized mode and by bus from each *freguesia* and each place to the nearest train station; and (2) the pairs of stations connected by services that allow for trips arriving at a given time of day and returning at another given time of day. The total travel times and interchange times between services were also registered. The data were obtained by analysing the rail schedules in the three years of analysis (1991, 2001, and 2011).

The sets of places considered as accessible for daily and weekly trips to work were obtained by selecting the records in this database that fulfil certain criteria, based on certain assumptions, as described below. It is assumed that bus services only connect rail stations with municipal capitals. At the origins and destinations other than municipal capitals, stations are accessed by non-motorized mode (walking or cycling). The bus or walk/cycle trips at either end are restricted to 15 minutes for daily trips to work and 30 minutes for weekly trips to work. Daily return trips to work also require arrival at the workplace between 8:00 and 9:30 and departure between 17:30 and 19:30 on all weekdays, restricting the rail section of the trip to a maximum of one hour. Weekly return trips require departure from the workplace on Friday after 17:30 and arrival at the hometown before 24:00, returning on Sunday after 14:00. A restriction of a maximum 30 minutes is placed on the waiting time at any intermediate station, to account for the disutility usually associated with this time (De Keizer et al. 2012). A set of eight variables is then produced: the number of places accessible by daily and weekly trips by road and rail, and the number of jobs in the places accessible by those trips.

### 3.4.3 Control Variables

Two sets of control variables were considered. The first set measures the characteristics of the natural and social environment. The second set measures the characteristics of the population. In a preliminary analysis, a large number of theoretically relevant variables were considered. The variables that were strongly correlated with other variables and that showed high post-estimation variance inflation factors (an indicator of multicollinearity in ordinary least squares regression) were excluded from the final set of explanatory variables.

The characteristics of the natural environment are assessed by a series of variables calculated from the *Environmental Atlas* published by the Portuguese Environmental Agency (APA). It is expected that out-migration (and population decline) is lower in places with warmer climates and with better conditions for agricultural activities.

The average temperature is an indicator of general climatic comfort and is included to account for the high variation among the northern and the southern parts of the Portuguese interior. A series of variables measure the suitability of the local environment for agricultural activities, including the average slope, the ratio between the area covered with water and agricultural area, and the proportion of soils classified as having no limitations to agriculture. The final variable is an indicator of forest fires and is expressed as the burnt area at the end of each period as a proportion of the total forested area at the beginning, using data from the CORINE ('coordination of information on the environment') land cover maps compiled by the European Union. This variable is included to control for the incidence of forest fires in the Portuguese countryside and their effects on the vulnerability of the local economy and society.

The social environment is assessed by two indicators of cultural capital and 'sense of place'. These are the number of places with historical or cultural importance, calculated from data in the *Environmental Atlas*, and the number of old businesses (more than 20 years old), which is estimated from the business database. It is expected that places with lower cultural capital and established businesses have higher out-migration and population decline.

A second set of control variables accounts for the characteristics of the population at the beginning of each period, calculated from census data. The set includes population size, the proportion of young people (15–24 years old), the proportions of low-qualified (four or less years of schooling) and graduates in the adult population, the unemployment rate, and the proportion of employment in the primary sector.

### 3.4.4 Models

Six models are estimated in each of the two periods, differing on the indicators of road and rail accessibility included. Each model includes indicators of ease of access to the transport network and indicators of the places accessible by the network. Models 1–3 include the number of places that can be accessed by road and rail transport and models 4–6 include the number of jobs at those places. Access to the network is measured alternatively as the time to the nearest access point to the motorway and rail networks (models 1 and 4) and as dummy variables for times to nearest access point of less than 15 minutes (models 2 and 5) and 30 minutes (models 3 and 6).

A spatial lag is included in all models, as preliminary estimations revealed that the model residuals were autocorrelated. The lag is the average of the population change in the neighbouring *freguesias*, based on the criterion of queen-type contiguity (shared borders). This variable accounts for the factors that are not captured in the control variables but affect population dynamics in the region where the *freguesias* are located, or alternatively, for the interrelationships among population dynamics in neighbouring *freguesias* via diminished economic opportunities and social networks.

## 3.5 RESULTS

The results of the model estimation are presented in Tables 3.2 and 3.3. The distance to the municipal capital is negatively and significantly related

*Table 3.2 Regressions of population change, 1991–2001*

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| dist. capital | −0.003 *** | −0.003 *** | −0.003 *** | −0.003 *** | −0.003 *** | −0.003 *** |
| road capitals | −0.001 | −0.002 | −0.001 | −0.002 | −0.003 | −0.002 |
| jobs | 0.055 *** | 0.055 *** | 0.055 *** | 0.055 *** | 0.055 *** | 0.055 *** |
| businesses | 0.004 *** | 0.004 *** | 0.005 *** | 0.004 *** | 0.005 *** | 0.005 *** |
| services | 0.007 *** | 0.007 *** | 0.007 *** | 0.008 *** | 0.008 *** | 0.007 *** |
| time junction | 0.0003*** | | | 0.0004*** | | |
| time < 15 | | −0.024 ** | | | −0.022 ** | |
| time < 30 | | | −0.002 | | | −0.003 |
| places (day) | 0.002 | 0.002 | 0.002 | | | |
| places (week) | 0.0002 | 0.001 | 0.001 | | | |
| jobs (day) | | | | 513.8 *** | 601.7 *** | 577.4 *** |
| jobs (week) | | | | −31.84 *** | −26.76 ** | −24.55 ** |
| time station | 0.0004* | | | 0.0003 | | |
| time < 15 | | −0.014 ** | | | −0.012 * | |
| time < 30 | | | −0.013 * | | | −0.010 |
| places (day) | −0.002 | −0.000 | −0.004 | | | |
| places (week) | 0.001 | 0.000 | 0.001 | | | |
| jobs (day) | | | | −10.18 | −10.99 | −12.41 |
| jobs (week) | | | | −0.515 | −0.367 | −0.379 |

| | | | | | | |
|---|---|---|---|---|---|---|
| temperature | 0.0003 | −0.001 | −0.001 | 0.001 | −0.0001 | 0.0001 |
| slope | −0.002 *** | −0.002 *** | −0.002 *** | −0.002 *** | −0.002 *** | −0.002 *** |
| water | 0.100 * | 0.118 ** | 0.113 * | 0.088 | 0.107 * | 0.103 * |
| good soil | −0.012 | −0.011 | −0.011 | −0.015 | −0.009 | −0.009 |
| burnt | 0.047 | 0.040 | 0.042 | 0.043 | 0.033 | 0.035 |
| heritage | −0.002 | −0.003 | −0.003 | −0.003 | −0.004 | −0.004 |
| old businesses | 0.009 *** | 0.009 *** | 0.009 *** | 0.009 *** | 0.009 *** | 0.009 *** |
| population | −0.005 | −0.003 | −0.003 | −0.004 | −0.001 | −0.002 |
| young | 0.341 *** | 0.347 *** | 0.338 *** | 0.258 *** | 0.282 *** | 0.275 *** |
| low-qualified | −0.158 *** | −0.152 *** | −0.141 *** | −0.160 *** | −0.151 *** | −0.142 *** |
| graduate | 1.407 *** | 1.421 *** | 1.393 *** | 1.378 *** | 1.382 *** | 1.363 *** |
| unemployed | −0.055 | −0.054 | −0.059 | −0.061 | −0.064 | −0.067 |
| agriculture | −0.095 *** | −0.090 *** | −0.093 *** | −0.113 *** | −0.108 *** | −0.108 *** |
| spatial lag | 0.246 *** | 0.253 *** | 0.259 *** | 0.235 *** | 0.257 *** | 0.261 *** |
| constant | 0.071 | 0.051 | 0.044 | 0.105 ** | 0.074 * | 0.067 |
| $R^2$ | 0.365 | 0.364 | 0.361 | 0.372 | 0.369 | 0.366 |

*Notes:* ***, **, *: significant at the 1%, 5% and 10% levels.

*Table 3.3 Regressions of population change, 2001–2011*

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| dist. capital | −0.003 *** | −0.003 *** | −0.003 *** | −0.003 *** | −0.003 *** | −0.003 *** |
| road capitals | −0.016 *** | −0.016 *** | −0.016 *** | −0.016 *** | −0.016 *** | −0.016 *** |
| jobs | 0.071 *** | 0.071 *** | 0.071 *** | 0.072 *** | 0.072 *** | 0.072 *** |
| businesses | 0.005 * | 0.005 * | 0.005 * | 0.005 ** | 0.005 ** | 0.005 ** |
| services | 0.006 ** | 0.006 ** | 0.006 ** | 0.006 ** | 0.006 ** | 0.006 ** |
| time junction | −0.0001 | | | −0.0001 | | |
| time < 15 | | 0.001 | | | 0.005 | |
| time < 30 | | | −0.001 | | | 0.001 |
| places (day) | 0.004 ** | 0.003 ** | 0.004 ** | | | |
| places (week) | −0.001 | −0.001 | −0.001 | | | |
| jobs (day) | | | | 0.267 ** | 0.214 * | 0.228 ** |
| jobs (week) | | | | −0.016 ** | −0.014 * | −0.013 * |
| time station | −0.001 * | | | −0.0003 | | |
| time < 15 | | 0.014 | | | 0.012 | |
| time < 30 | | | 0.030 *** | | | 0.029 *** |
| places (day) | −0.022 | −0.020 | −0.021 | | | |
| places (week) | −0.0006 | 0.0006 | 0.0007 | | | |
| jobs (day) | | | | −0.002 | −0.001 | −0.002 |
| jobs (week) | | | | 0.0002 | 0.0001 | 0.0001 |

| | | | | | | |
|---|---|---|---|---|---|---|
| temperature | −0.002 | −0.003 ** | −0.002 * | −0.002 | −0.003 ** | −0.003 ** |
| slope | −0.002 *** | −0.002 *** | −0.002 *** | −0.002 *** | −0.002 *** | −0.002 *** |
| water | 0.079 | 0.075 | 0.081 | 0.077 | 0.070 | 0.075 |
| good soil | 0.035 ** | 0.031 * | 0.032 * | 0.032 * | 0.027 | 0.027 |
| burnt | −0.078 | −0.078 | −0.073 | −0.086 | −0.089 | −0.086 |
| heritage | −0.0005 | −0.0004 | −0.001 | −0.001 | −0.001 | −0.001 |
| old businesses | 0.006 *** | 0.006 ** | 0.006 *** | 0.007 *** | 0.007 *** | 0.007 *** |
| population | 0.015 *** | 0.015 *** | 0.015 *** | 0.016 *** | 0.015 *** | 0.015 *** |
| young | 0.089 | 0.079 | 0.079 | 0.039 | 0.028 | 0.027 |
| low-qualified | −0.041 | −0.043 | −0.041 | −0.050 | −0.053 | −0.052 |
| graduate | 0.547 *** | 0.558 *** | 0.550 *** | 0.535 *** | 0.559 *** | 0.556 *** |
| unemployed | −0.061 | −0.057 | −0.059 | −0.078 * | −0.071 * | −0.073 * |
| agriculture | −0.046 *** | −0.043 *** | −0.045 *** | −0.056 *** | −0.049 *** | −0.052 *** |
| spatial lag | 0.245 *** | 0.242 *** | 0.241 *** | 0.244 *** | 0.240 *** | 0.239 *** |
| constant | −0.003 | 0.006 | 0.006 | 0.018 | 0.031 | 0.029 |
| $R^2$ | 0.301 | 0.300 | 0.303 | 0.302 | 0.301 | 0.303 |

*Notes:* ***, **, *: significant at the 1%, 5% and 10% levels.

to population change, which is consistent with the theory that geographic isolation is a pull factor for migration. However, the dummy for the location of the *freguesias* along roads linking municipal capitals is also negatively and significantly related to population change in the 2001–2011 period, suggesting that the existence of direct links with central places may also facilitate out-migration.

The coefficients of the three measures of local accessibility are positive and significant in both years, confirming prior expectations. The changes in the times to the nearest motorway junction are only significant in the 1991–2001 period. The coefficient is positive, which means that the higher the reduction in time to motorways, the higher the population decline. The results of the variables measuring access to the railway network in the same period are consistent with that pattern: the higher the increase in the time to railway stations, the lower the population decline is. The changes in the dummies for the time thresholds are also significant. The loss of a station within a radius of either 15 or 30 minutes is linked with population decline. The results differ in the 2001–2011 period, where the coefficient for the time to the nearest station is negative and the coefficient for the change in the 30-minutes station dummy is positive. In other words, the increase in time to the nearest station and the loss of access to a station increase population decline.

In both years, the coefficient of the change in the number of jobs accessible by day trips by car is significant and positive (the higher the change in the number of jobs, the lower the population decline in a given *freguesia*). However, the coefficient of the change in the number of jobs accessible by weekly trips by car is negative (the higher the change in the number of jobs, the higher the population decline). None of the rail accessibility variables were found to be statistically significant.

The natural and social environment control variables that are significant tend to have the expected sign: the population decline is higher in areas with lower temperature, higher slopes, poorer soils, less water and fewer old business. The demographic control variables are also significant in almost all cases and confirm that population decline is higher in areas with smaller population, with higher proportion of older and less qualified people, and in areas with higher unemployment and share of agricultural employment.

The influence of the spatial lag variable is always positive and significant. This result is consistent with those of other studies on the relationship between rural accessibility and population change (Voss and Chi 2006; Ribeiro et al. 2010; Koopmans et al. 2012).

## 3.6 DISCUSSION AND CONCLUSIONS

This chapter tested the existence of links between three patterns observed in the Portuguese interior regions in the last two decades: population decline, investment in the road network and disinvestment in the railway network. The study contributes to the accessibility literature by comparing the impact of access to the road and rail networks and to nearby and distant places, accessible on a daily or weekly basis. The impact of accessibility on population change is controlled for the natural, social and demographic context. The findings show that population decline is significantly associated with several accessibility measures in different periods, including the location of the *freguesias* along roads linking municipal capitals, the changes in the times to the nearest motorway junction and rail station, the existence of a rail station in the vicinity of a place, and the change in the number of jobs accessible.

The results suggest that the investment in the road infrastructure does not promote territorial cohesion, at least when cohesion is assessed by population dynamics. The improvement of access from rural areas to regional or national centres can in fact contribute to population decline as it creates conditions for out-migration. This is an effect specific to the nature of transport infrastructure, in contrast with other types of public investment and policies, such as the promotion of employment or the provision of services in rural areas. Changes in the number of jobs and services were indeed found to be significantly and positively related to population change in all models estimated.

The models also show that the closures of railway lines are not necessarily linked with population decline. This link was found in the period 2001–2011 but not in 1991–2001, when population decline was associated with the absence of closures. Moreover, these links were found for the dummy variable indicating the existence of a station in the vicinity of a *freguesia*, but not for the accessibility measures that incorporate the suitability of railway services in meeting the travel needs of the populations. The absence of significant links for these measures may be due to the fact that the existing services before the lines were closed were no longer considered as valid options by the population, as they did not allow return trips to the relevant destinations on the required days of the week and at the required times of day. The increase in the number of places connected by the network (through rescheduling of direct services or creating of bus feeder lines) may improve rail accessibility and have a significant positive impact in population dynamics.

In the context of accessibility research, this chapter confirms the relevance of isolating the impacts of different aspects of accessibility on population change. These aspects are related to the types of destinations people need to access, and to the modes of transport they consider as options. In each period, and possibly in each study area, only some aspects will be significantly related to population change, as the accessibility needs of the populations are different and change over time. The analysis of other contexts may require the inclusion of dimensions that were not tested in this chapter, such as the accessibility of students and access by coach services.

Other methodological questions still require further development. Causality is one of these questions, as the links between road and population change tend to be bidirectional (Voss and Chi 2006). For example, decisions about railway closures may be based on the lack of economic viability of the closed lines, due to low demand, which in turn is caused in part by population decline. The closure of the lines may then contribute to further population decline. The possible endogeneity of the accessibility variable may explain the relatively low goodness of fit of the models estimated in this chapter. The correction of this issue is complex as it is difficult to model the determinants of changes in accessibility. This is especially true in the case of railway closures, which depend on factors that are difficult to measure, such as the political context, the political power of the local populations living along the lines closed, and relationships between central and local governments.

Another important question is the time scale of effects. The links between accessibility and population change may operate with a certain time lag. This aspect can be incorporated in the analysis by using autoregressive models (Koopmans et al. 2012) or explanatory variables for the number of years since access to the network started or was cut (Voss and Chi 2006).

Finally, it is important to notice that population change is in fact a composite variable, the sum of the natural population change and net migration. The two components may respond differently to changes in accessibility and should then be modelled separately. However, this may not always be feasible, as birth, death and migration statistics may not be available for researchers at a sufficiently disaggregated level.

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