

# Accessibility and Spatial Inequalities in Greece

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**Abstract** Accessibility suggests a major issue in rural areas. Remoteness or inaccessibility is known to amplify rural deprivation and suspend sustainable regional development. Many rural areas in Greece suffer from remoteness mainly because of a varying and continuously alternating terrain. A diverse space is shaped by more than 70% mountain areas, hundreds of inhabited islands in an insular area almost the size of the mainland and intense variation in population distribution between the large urban agglomerations and the periphery. In this paper, a geographical remoteness index for Greece is presented that can capture the required scale of analysis and the distinct characteristics of Greek space. The index is localized and evaluated using empirical and theoretical methods and several demographic and network geostatistics. Finally, we examine the relationship of the index and critical socioeconomic variables in order to associate accessibility with spatial inequalities. Spatial regression models are used that uncover the impact of remoteness in certain key development aspects, namely economy, human capital and infrastructures. Potentially, accessibility may be used as an evaluation tool to redirect policies for spatial equity.

**Keywords** Remoteness · Accessibility · Spatial equity · Spatial regression · Greece

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## Introduction

Greece varies vastly in geography. According to Nordregio (2004), Greece is in the top five of the most mountainous countries in Europe with mountain municipalities covering 77.9% of the country's total area. On the other hand, Greece is a country with rich insular space. Coastline is 17,400 km long, of which, around 10,000 km belong to islands, and total territorial sea is 114,507 km<sup>2</sup> (EC 2011) almost 86% of the land area. More than 100 islands are inhabited, holding 13.3% of the total population according to 2011 census, but tourism and visitation is extremely heavy in summer months (Kizos 2007; Spilanis et al. 2012). Additionally, population is unevenly distributed. Since 1930, due to several geopolitical reasons, urban agglomerations have been mostly concentrated into two major poles, those of Athens and Thessaloniki, holding almost half of the Greek population (Hastaoglou et al. 1987; Hoggart et al. 2014; Wagstaff 1999). These circumstances have led to the abandonment of mountainous Greece, a partly abandonment of the fewer plain rural areas, and the transition of the islands to seasonal resorts. Thus, Greece carries immense national disparities and many rural areas suffer from peripherality because of remoteness (Skuras et al. 2000).

Populated localities exist in mountainous Greece where the rugged terrain and the poor road network quality render them remote in terms of accessibility to basic health and education services. In addition, access in some islands can be very difficult in winter when tourism activity is low and the ferry network is limited (Kizos 2007). The continuous alteration of mountainous, insular and plain areas, even in a relatively small country, causes many accessibility related issues. The need for an accessibility model that can produce a high spatial level of analysis to catch those variations and provide robust policy directions is apparent.

## Accessibility and Remoteness Concepts

Accessibility has formally joined the regional development research as an important factor. There are successful examples where accessibility is being used as a tool for various analyses and policy making, like in UK and Australia (Farrington 2007; Glover and Tennant 2003; Páez et al. 2012). Accessibility affects a number of indices like rurality (Caschili et al. 2015; Higgs and White 2000; Waldorf 2006) and peripherality (Copus 2001; Schürmann and Talaat 2002; Spiekermann and Neubauer 2002; Spiekermann and Wegener 2006) that are crucial in regional development.

The core idea behind accessibility models is that the accessibility of a place can be measured by a two-part function where one factor represents the amount of services or the general attractiveness of the destination and the other the impedance function of the spatial-temporal constraints that need to be overcome in order to reach that destination. Understandably, as simple as it may seem conceptually, there are many components that can be accounted in those two factors. A lot of researchers have made reviews on accessibility measures over the years, bringing out several conceptual, theoretical, methodological and computational aspects and frameworks (Geurs and Van Wee 2004; Guagliardo 2004; Handy and Niemeier 1997; Kwan 1998; Li and Lu 2005; Páez et al. 2012; Pirie 1979; Pooler 1987; Spiekermann and Neubauer 2002; Wang 2012). Despite the different approaches of evaluation or even the different initial theoretical frameworks, it is generally agreed that accessibility measures can get exceedingly complex as more factors are added in the models. Thus, in practice, it is better to provide models that are

simple to operate, understand, and answer specific research questions, while of course including the limitations and constraints that may arise.

Remoteness can be seen as the geographical inaccessibility to certain locations. Remoteness affects at least three major aspects of a region, namely local culture and communities, the environment, and economic development (Coccosis 2001). Not every impact of remoteness can be considered as negative. In fact, tourism industry can benefit from remoteness and peripherality (Copus 2001), like for instance from the preservation of natural and cultural heritage. Of course, whatever resources may exist in a remote location, they are hard to be identified and valorised because remoteness and isolation is often associated with lack of human capital (Labrianidis 2006).

### Accessibility/ Remoteness in Greece

There is limited literature concerning accessibility in Greece. Schürmann and Talaat (2002) used accessibility and peripherality indicators in order to identify remote geographical entities in EU countries, whose accessibility may be improved with network infrastructures. The study produced interesting results about the economic activity of Greece in relation to accessibility, rendering it one of the most poor and peripheral countries of the EU. However, intraregional variations and spatially more detailed conclusions are not very clear due to the level of analysis (level 3 of the Nomenclature of Territorial Units for Statistics, NUTS 3) and the relation to EU countries with far better network infrastructures and higher economic activity. Other notable researches that address specific regions and accessibility issues in Greece are the work of Panebianco and Schürmann (2002) that studied the impacts of Egnatia motorway in various socio-economic and spatial aspects focusing on accessibility, and the work of Spilanis et al. (2012) that measured the accessibility of certain Greek islands using time travel to services. There has not been yet a study addressing accessibility and its impact in Greece as a single geographical entity.

### Methods

The needs of this research are directed towards the rural rather than the urban aspect of accessibility, so a model is required that mainly delineates accessibility in terms of rurality or vice versa. Thus, an accessibility model for Greece has been produced, based on ARIA (Accessibility/Remoteness Index of Australia) (Glover and Tennant 2003; Trewin 2001). ARIA offers some considerable advantages for the purposes of this study. Firstly, it can act as a framework to define rurality (Farmer et al. 2001), and it is overall oriented towards rural areas (Glover and Tennant 2003). In addition, it is a tested and operational model that is used for the official remoteness classification in the Australian Standard Geographical Classification (ASGC) of the Australian Bureau of Statistics (ABS) (Trewin 2001) and has being implemented in a significant number of studies (Calver et al. 2007; Eckert et al. 2004; McNamara and Rosenwax 2007; Murray et al. 2004, 2005; Poulos et al. 2009; Zilkens et al. 2009). Furthermore, the model is simple, comprehensive and transparent (Glover and Tennant 2003; Trewin 2001). As Geurs and Van Wee (2004), Straatemeier and Bertolini (2008), and Vandenbulcke et al. (2009), among others, have suggested a simpler model is more communicable and understandable by other researchers and/or administrators.

Along with the accessibility/remoteness index, a spatial analysis is taking place in order to uncover the effects of inaccessibility in Greece. It has been discussed that accessibility indices may be used as an evaluation framework to produce policies for spatial equity (Van Wee 2016; Wee and Geurs 2011). Inaccessibility to services may lead to rural deprivation (Farmer et al. 2001) and it has been suggested that most remote settlements in Greece lack in terms of human capital, economy and infrastructures. In order to test this hypothesis, the geographical distribution of certain socioeconomic variables is analysed based on the accessibility. Spatial autocorrelation models, e.g. Moran's I (Moran 1950), and spatial regression models have been used, bringing forth the spatial dimension of the issue, a crucial aspect for demographic and social related analysis that sometimes is neglected (Chi and Zhu 2008).

### Localizing the Accessibility/Remoteness Index

ARIA is a location-based accessibility model that measures the accessibility/remoteness of populated localities, where a subset of them act as service centres, by summing the distance ratios of the closest services centres. The service centres are divided to classes based on population size. The distance ratio for each service centre category is the distance to the closest service centre (of that category) to the mean distance of all localities to their closest service centre of each category, and it is measured only for higher service centres (higher population). For the distance in sea, a proportional to distance weight (ranging from 2 to 10) has been given to express the differentiation with the land travel. Also, a threshold for the distance ratio was set (3), as to exclude extreme values and bound the measurement to a standard range. For more information about the model, refer to Glover and Tennant (2003), Trewin (2001), and the ARIA official website.<sup>1</sup>

A location-based model cannot easily capture the individual's perspective regarding travel choices. Moreover, it mainly measures accessibility from a normative perspective, that is, where people ought to travel and not from the positive one, meaning where people actually travel (Páez et al. 2012). However, an argument could be made here; when talking about health and education services (indirectly the main factors in the activity function of the ARIA model) and specifically for Greece, where those services are mainly public and the quality ought to be the same everywhere, the normative aspect of the accessibility should match the positive one and the travel choices of people should be limited to the closest facility that offers such services.

ARIA makes use of the general formulation of gravity-based accessibility models that can be expressed by the following equation:

$$A_i = \sum_j g(W_j) f(c_{ij}) \quad (1)$$

where  $A_i$  the accessibility of location  $i$ ,  $g(W_j)$  the services, activity, or general attractiveness function of location  $j$ , and  $f(c_{ij})$  the impedance function expressing the cost to reach location  $j$  from location  $i$ . In the case of the ARIA model the activity function ( $g(W_j)$ ) is either 0 or 1 depending on the  $j$  service centre. If the  $j$  service centre is higher (in terms of services) than the locality  $i$ , then  $g(W_j)$  is 1 otherwise is 0. In addition, the

<sup>1</sup> [https://www.adelaide.edu.au/hugo-centre/spatial\\_data/aria/](https://www.adelaide.edu.au/hugo-centre/spatial_data/aria/)

impedance factor is expressed as the ratio of the  $ij$  distance to the average  $ij$  distance of every locality  $i$  to the closest service centre  $j$ . The gravity-based accessibility models normally use various forms of the impedance function such as power or logistic with the negative exponential being the more widely used (Geurs and Van Wee 2004). The use of the ratio provides a form of normalization in the measurement, implying that travel cost should start to increase significantly for distances above the average.

The question is if the ARIA model can be applied in a study area that is quite different from the applied one, and to what extent should it be modified in order to provide accurate results. The two countries differ from each other in geography and demography. Australia's total area is around 7.5 million km<sup>2</sup>, almost 57 times that of Greece, while its population is slightly over double of that of Greece. Territorial sea for Australia accounts for about 11% of the land area,<sup>2</sup> while for Greece that number is 86%. Population distribution also varies, partly because of the much larger area of Australia. Australia has 11 cities with population over 200,000, while Greece only has two. The key feature that allows the use of the model in another study area is the employment of a ratio instead of absolute values in the calculation of the travel cost. In this manner, the relative accessibility of each location is measured inside a delimited space. Unavoidably, while it is possible to use the model in different areas, the resulted index cannot be used to compare those areas in terms of accessibility.

Whereas the ARIA model has a lot of advantages for the purposes of this study, modifications are needed in both parts of the equation, in order to capture the characteristics of the study area. For the activity faction the main issue is the classification of the localities to service centres. Considering the variations between the two countries, a classification simply based on a clustering algorithm might be problematic. As for the impedance factor, the form of ratio instead of absolute values renders the scale of the study area irrelevant to the results, nonetheless, modifications are required in this part as well. Understandably, Australia's main issues concerning accessibility is the mainland where vast non-inhabited areas exist and travel time is considerably long. Greece is not the same and, apart from some mountain areas in mainland, the longer travel times may be found in islands. The travel cost should better reflect the difficulties that arise in the insular space, which is a very important aspect of the Greek space. Finally, a thorough statistical examination of the calculated distance ratios can reveal issues or inconsistencies both in the classification of the service centres and the estimation of travel cost.

### *Classification of Service Centres*

The classification of settlements into service centres categories has been performed in three steps – identifying urban areas, examining correlations between population size and services, and clustering by population size. Urban areas have been partially excluded from the index. That is, although the relative accessibility/remoteness between urban areas is measured, those areas are accounted as a single entity besides the variations in accessibility that may be found inside them. It is true that urban areas can show a great variation in accessibility but this is related to a large number of factors like public transportation, congestion, spatial planning

<sup>2</sup> <http://www.ga.gov.au/ausgeonews/ausgeonews200903/limits.jsp>

and more (Guagliardo 2004), but it is not in the scope of this study to identify urban accessibility patterns. In order to identify urban regions, the Urban-Rural typology of EU (eurostat 2016), has been applied, using the GEOSTAT 1 km<sup>2</sup> population grid data (Eurostat 2012). The application of the typology resulted in 138 distinct urban areas with population ranging from 5040 to 3,420,000.

Statistical analysis with Ordinary Least Square (OLS) linear regression has been performed in order to identify a connection between population size and services availability. Spatial data for health and education services have been retrieved from the Hellenic Centre for Disease Control & Prevention (HCDCP 2008) and the Greek School Network<sup>3</sup> of the Ministry of Culture, Education and Religious Affairs. The regressions have been made with the adjusted urban population of settlements, meaning that each urban settlement has been given the population of the urban area that it belongs. Results suggest that there is a strong connection between population size of the settlements and the availability of health and education services (Table 1).

The threshold of 5000 population of the EU urban-rural typology has been used as a reference point in the classification of settlements to service centres. The natural breaks method has been applied to settlements with population size greater than 5000. Almost in any number of clusters, there is a clear distinction of the two large urban agglomerations (Athens and Thessaloniki) as two different groups. This is attributed to the great difference of population size compared to other cities (Table 2).

The distinction of Athens and Thessaloniki in different groups is further supported by some other data. Since 1960, urbanisation is concentrating the major social and economic activity of the country in Athens (Saitis and Saiti 2004). For instance, from the 120 general hospitals of the country, 42 are concentrated in Athens and 11 in Thessaloniki, while the rest of the major cities have 3 or less. Moreover, Athens has much more tourism activity than Thessaloniki and, thus, better related infrastructures, like transportation (e.g. metro, larger port and airport with many more international destinations).

Between 100,000 and 200,000 population, 4 cities may be found (Patra, Larissa, Volos and Heraklion) that have been selected to represent a single group because of several accessibility related facts. Patra, Larissa and Volos are connected with the national railway, as well as several major motorways. In addition, three of the larger ports in Greece are located in Patra, Volos and Heraklion. Lastly, all four cities retain international airports.

In the range of 5000 to 100,000 population a clear distinction based on empirical data or service availability could not be made, so the simple natural breaks have been kept, breaking the values into two groups (5000–30,000 and 30,000–100,000).

Below 5000 population the classification is difficult, as the distribution of population and services is not normal. The thresholds of 200 and 1000 from the Australian Bureau of Statistics (ABS) cities and towns classification (Trewin 2001) that are employed in the ARIA methodology have been kept. These thresholds are also employed by the Hellenic Statistical Authority (EL.STAT.) in the settlements' classification based on population size. Furthermore, the Natural Breaks classification into three groups gives breaks relatively close to those values (400 and 1600 respectively). Finally, a weak correlation has been found for settlements of 200 to 5000 population with the distance of the closest school and health centre, using logarithmic conversions (Table 1). For the

<sup>3</sup> <http://www.sch.gr>

**Table 1** Ordinary Least Square (OLS) linear regressions of population and various health and education service availability variables

Regression	Dependent variable	Independent <i>t</i> variable	R <sup>2</sup>	<i>p</i>
<b>Health services availability</b>				
City (>5000 population) size - number of hospitals	Number of hospitals in 25 km radius	urban population	0.94	0.00
City (>5000 population) size - number of hospital beds	Number of hospital beds in 25 km radius	urban population	0.92	0.00
Settlement size - distance to closest hospital	Log of distance to closest hospital	Log of population	0.15	0.00
<b>Education services availability</b>				
Settlement size - number of elementary schools	Number of elementary schools in 5 km radius	population	0.94	0.00
Settlement size - number of high schools	Number of high schools in 5 km radius	population	0.95	0.00
Settlement size - distance to closest elementary school	Log of distance to closest elementary school	Log of population	0.16	0.00
Settlement size - distance to closest high school	Log of distance to closest high school	Log of population	0.19	0.00
Settlement (200–5000 population) - distance to closest elementary school	Log of distance to closest elementary school	Log of population	0.07	0.00
Settlement (200–5000 population) - distance to closest elementary school	Log of distance to closest high school	Log of population	0.12	0.00

settlements below 200 population, there is no correlation with distance to services. The final classification of the settlements into service centres can be seen in Table 2.

*Islands and Weighted Distance*

Weights have been given for sea travel with regard to two major aspects. First, the proximity penalty for sea routes has been excluded and, second, weights are based on

**Table 2** Results of the settlements’ classification to service centres

Service centre/ settlement category	Population range	Number of service centres/settlements	%	Total population	%	%	%
A (Athens)	> 900,000	1	0.01	3,400,000	4,220,000	31.51	39.11
B (Thessaloniki)	200,000–900,000	1	0.01	820,000		7.60	
C	100,000–200,000	4	0.03	650,000	650,000	6.02	6.02
D	30,000–100,000	23	0.17	1,500,000	1,500,000	13.90	13.90
E	5000–30,000	108	0.82	1,200,000	1,200,000	11.12	11.12
F	1000–5000	663	5.02	1,250,000	1,250,000	11.58	11.58
G	200–1000	3340	25.28	1,470,000	1,470,000	13.62	13.62
Rest	0–200	9074	68.67	500,000	500,000	4.63	4.63



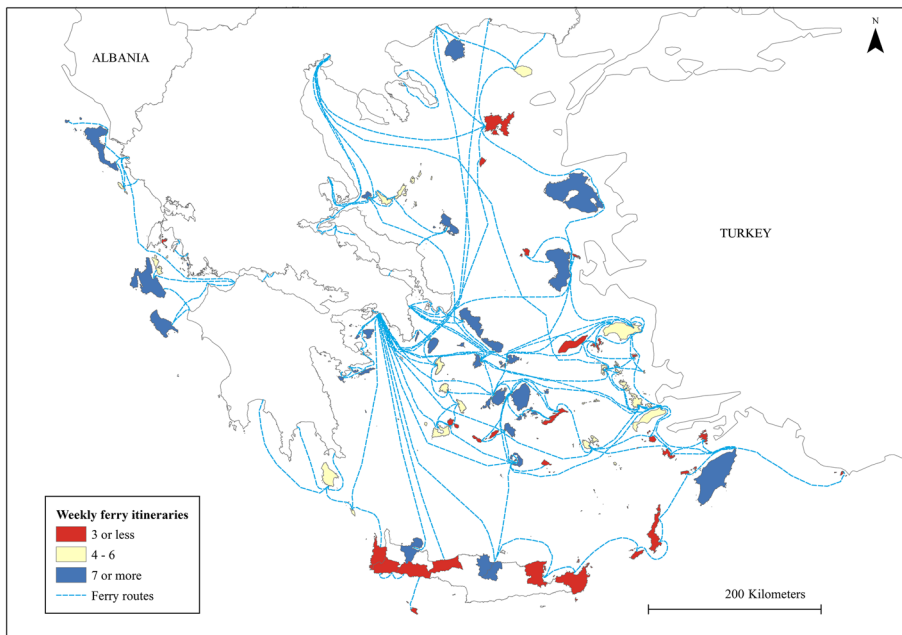
the weekly itineraries of ferries. The proximity penalty has been excluded for the reason that, generally, sea traveling is not rare or unfamiliar in Greece. It is common practice for close islands or coasts to be connected with ferries very frequent and in some cases even less than hourly. For instance, in Rio-Antirrio canal, though there is a bridge, there are still frequent ferry itineraries and, after the 2009 recession, are even preferred by travellers because of the lower fare compared to the bridge's toll.

In contrast with the proximity penalty, ferry itineraries are much more important for Greek insular space, and especially for more remote islands. The sea distance weights of the model are based on the weekly ferry itineraries that connect islands to the mainland in winter (Fig. 1). Winter has been chosen for it is the intention of this research to measure remoteness in islands with respect to the resident's perspective and not to seasonal visitors. Thus, the weight for sea distance is calculated through the expression:

$$W_{(I_w)} = \begin{cases} 1.5, & I_w > 7 \\ 1.5 + \left(1 - \frac{I_w}{7}\right), & 1 \leq I_w \leq 7 \\ 3, & I_w < 1 \end{cases} \quad (2)$$

where  $W_{(I_w)}$ , the sea distance weight and  $I_w$ , the weekly ferry itineraries. The above expression guarantees that:

- (1) In any case, sea travel is more difficult than land travel. The minimum weight of 1.5 is lower than the ARIA minimum (2) since sea traveling is more common and needed in Greece but still not equal with land traveling. While mountainous Greece is traversed by a bad quality road network, service availability is always



**Fig. 1** Weekly ferry itineraries in Greece for winter



- worse in islands compared to mainland because of complex or unavailable transport choices (Spilanis et al. 2012).
- (2) Weekly ferry itineraries affect the weighted distance.
  - (3) Extreme values are avoided, similar to the ARIA model.

### *Distance from Service Centres*

In order to compute the distance ratio of each settlement (distance to closest service centre to mean distance), the distance of each settlement to the closest service centre of each category has been calculated. Geospatial data for the road network and sea routes have been retrieved from the Road Network Planning Administration (2015) and the EuroGeographics (2015) website. The road distance is calculated as the given length of the network in meters, while the sea distance is calculated from the length of the seaway lines by applying the relevant weight. Statistics of the results can be seen in Table 3. The statistical analysis shows that the classified service centres are evenly distributed in the Greek space, as the mean, maximum, and standard deviation values decrease proportionally to the service centre size. An exception is found for the second category - the settlements inside the urban area of Thessaloniki. This does not affect the model's credibility since in the calculation of the index, if the closest centre of a higher category is closer than the closer centre of a lower category, the centre of the higher category is selected for the distance ratio calculation. Since Thessaloniki is located in North Greece, most of the southern settlements' distance to category B (Thessaloniki urban centre) is calculated with the distance to Athens. The addition of one extra category does not affect the overall relative accessibility of the settlements but it adds a spatial differentiation to the North and South Greece with respect to the two largest urban centres and their magnitude in service availability.

### **Correlation with Socioeconomic Characteristics**

Correlation of the accessibility/remoteness index and various socioeconomic indicators has been applied on settlement level. The data that have been selected to represent indicators of spatial inequalities in economy, human capital and infrastructures are:

**Table 3** Major statistics of weighted distance to service centres

SC	Weighted distance to service centres (SC) in kilometres		
	Mean	Max	STD
A (Athens)	369	1442	194
B (Thessaloniki)	499	1903	316
C	220	1317	196
D	85	534	90
E	52	459	67
F	24	383	38
G	6	248	13

- Average household income from tax data at postal code level (economy). Derived from the General Secretary of Information Systems of the Ministry of Finance (GSIS 2011), geocoded using the postal code, and interpolated for the whole Greece. Each settlement has been assigned a value using the interpolation results.
- Price of Unleaded95 petrol gas (economy). Derived from the Fuel Prices Observatory (2012) of the Ministry of Finance, geocoded using the postal address of the gas station, and interpolated for the whole Greece. Each settlement has been assigned a value from the interpolation results.
- Population over 50 years of age at settlement level (human capital). Acquired from Hellenic Statistical Authority (EL.STAT. 2016b). The variable is set as the ratio of population over 50 years of age to the total population.
- Population over 30 with higher education e.g. college or university at settlement level (human capital). Acquired from Hellenic Statistical Authority (EL.STAT. 2017). The variable is set as the ratio of the population that holds a college or university degree to the population over 30 years of age.
- Percentage of households without internet connection at settlement level (infrastructures). Acquired from Hellenic Statistical Authority (EL.STAT. 2016a). The variable is set as the ratio of the households without internet connection to the total households.

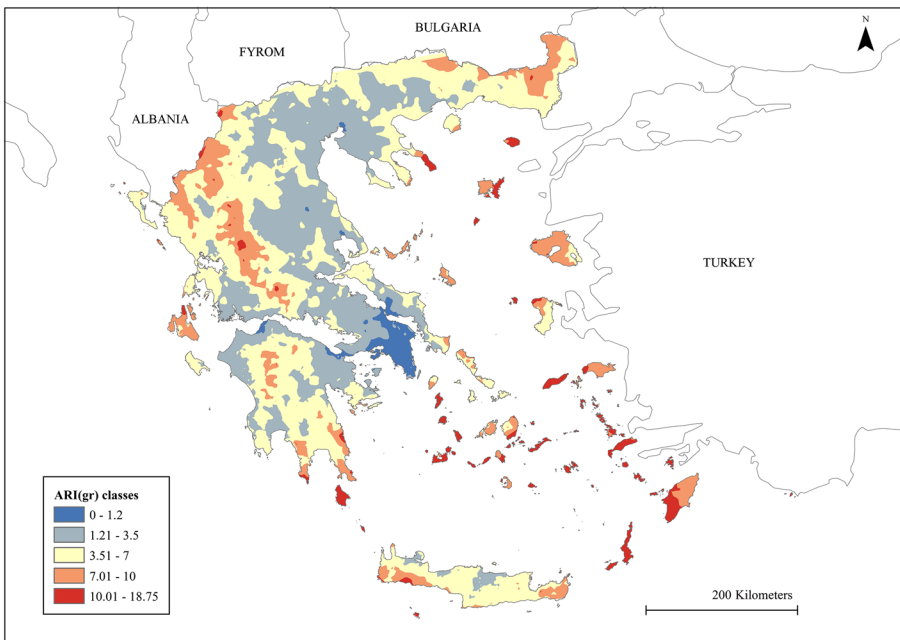
Due to the high spatial autocorrelation of the index and the socioeconomic variables, spatial dependence tests and spatial regression have been used in order to eliminate inefficient or biased results. Analysis have been performed using the GeoDa software (Anselin et al. 2010).

## Results

The application of the model produces an index of continuous values for each settlement that ranges between 0 and 18 (6 categories of service centres and a threshold of 3 for each distance ratio), the Accessibility/ Remoteness Index of Greece (ARI(gr)). Furthermore, a classification of the index has been made using the Natural Breaks classification as a base and applying the following criteria:

- (1) The first category “Highly Accessible” includes all the large cities of Greece (more than 100,000 population) (Index value  $\leq 1.2$ ).
- (2) The second category “Accessible” includes the rest of the cities in mainland plus the 3 major cities of the island of Crete ( $1.2 \leq$  Index value  $\leq 3.5$ ).
- (3) The third category “Moderate Accessible” includes the larger in terms of population islands ( $3.5 \leq$  Index value  $\leq 7.0$ ).
- (4) The fourth category “Remote” is not excluding some high values of the index in the mainland ( $7.0 \leq$  Index value  $\leq 10.0$ ).
- (5) The rest of the values are classified as “Very Remote” ( $10.0 \leq$  Index value  $\leq 18.0$ ).

The final results of the index, interpolated for the whole Greece, can be seen in Fig. 2. Table 4 shows the resident population, the de facto population, and the area



**Fig. 2** Natural neighbours interpolation of the settlements' index value and custom classification based on Natural Breaks method and certain criteria

of each ARI(gr) category. It is remarkable that, while the upper and lower category have almost the same area, the difference in population distribution is considerable (Table 4), a fact that expresses the level of population concentration in urban agglomerations and rural deprivation in Greece.

### Index Evaluation

In order to evaluate the index two methods are employed. Firstly, a sensitivity analysis is performed by altering the network. Secondly, the spatial distribution of the index is examined through spatial autocorrelation methods.

#### *Impact of Major Network Infrastructures*

The impact of two major network infrastructures the Egnatia Motorway<sup>4</sup> and the Rio–Antirrio Bridge<sup>5</sup> in the ARI(gr) model has been tested. Results can be seen in Figs. 3 and 4 respectively. Based on the index values, Egnatia Motorway seem to affect more the peripheral regions of North Greece than the central. This is a reasonable deduction since in North-Central Greece the urban agglomeration of Thessaloniki is much easier reachable from the periphery. Moreover, the urban centre was not affected by the Egnatia Motorway in terms of accessibility to basic services.

<sup>4</sup> <http://www.egnatia.eu/page/default.asp?id=5&la=2>

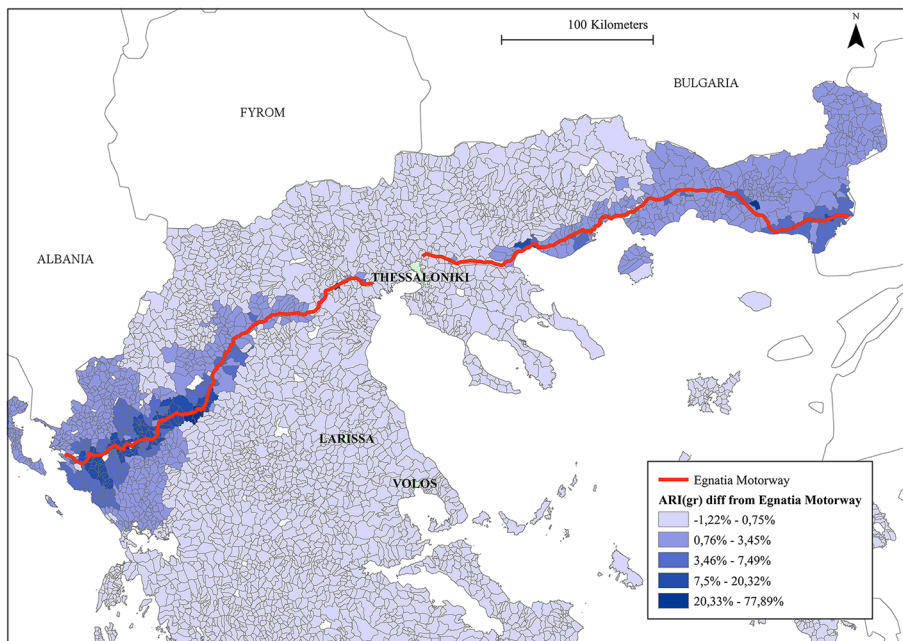
<sup>5</sup> [https://en.wikipedia.org/wiki/Rio%E2%80%93Antirrio\\_bridge](https://en.wikipedia.org/wiki/Rio%E2%80%93Antirrio_bridge)

**Table 4** Population and area of each ARI(gr) class

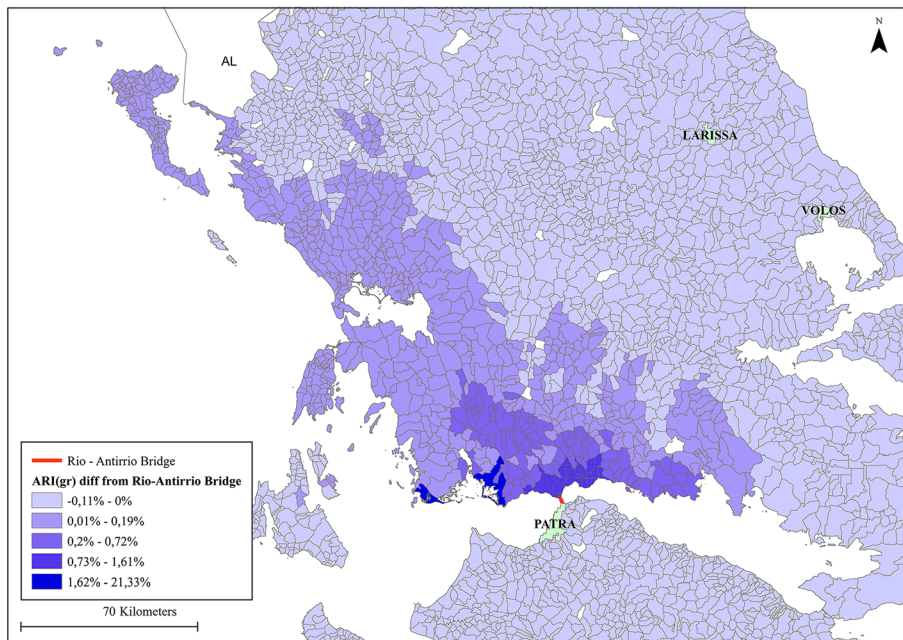
ARI(gr) class	Resident population		De Facto population		Area (km <sup>2</sup> )	Area (%)
Very accessible	5,021,381	47%	4,975,378	46%	3710	3
Accessible	3,717,712	35%	3,758,748	35%	47,877	37
Moderate accessible	1,506,218	14%	1,565,886	14%	56,665	43
Remote	375,137	3%	431,756	4%	17,736	14
Very remote	107,910	1%	121,304	1%	5134	4

For the Rio-Antirrio Bridge, the results are similarly acceptable. The Bridge helped to alleviate accessibility issues in Western Greece, which is cut off from the major urban centres in the east by the Pindus mountain range. Variance in accessibility is not as high as with the Egnatia Motorway, since the gain in time may be important but the monetary cost of traveling is still relatively high (bridge's tolls) and is well expressed by the difference between the road network and the weighted sea route distance.

In both cases, variations in remoteness are very well documented in numbers. For instance, Egnatia motorway affects the West mountainous Greece more intense but in a less dispersed way, while, in East Greece (where plain areas are dominant), remoteness has been alleviated mildly and in a wider area. For Rio-Antirrio Bridge, the peak values are found in the urban areas of West Greece, where accessibility to service centres affects more population.



**Fig. 3** Percentage difference of ARI(gr) by running the model with and without Egnatia Motorway in the road network



**Fig. 4** Percentage difference of ARI(gr) by running the model with and without Rio – Antirio Bridge in the road network

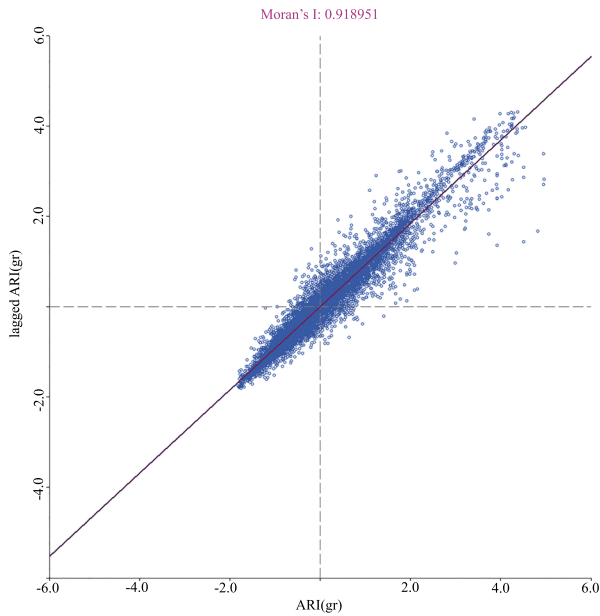
### *Spatial Autocorrelation*

The index has a very high local spatial autocorrelation. Univariate Local Moran's I is 0.92 (Fig. 5), and the LISA cluster map shows significant clusters of the index in almost half of the point values (Fig. 6). The clusters follow some major geographical characteristics of the Greek space. Clusters of high index values are located mainly in West Greece, where the most mountain regions are located, and in most islands. In contrast, in the East mainland the low valued clusters are located, where the major cities and motorways may be found (Fig. 6).

### **Remoteness and Equity in Economy, Human Capital and Infrastructures**

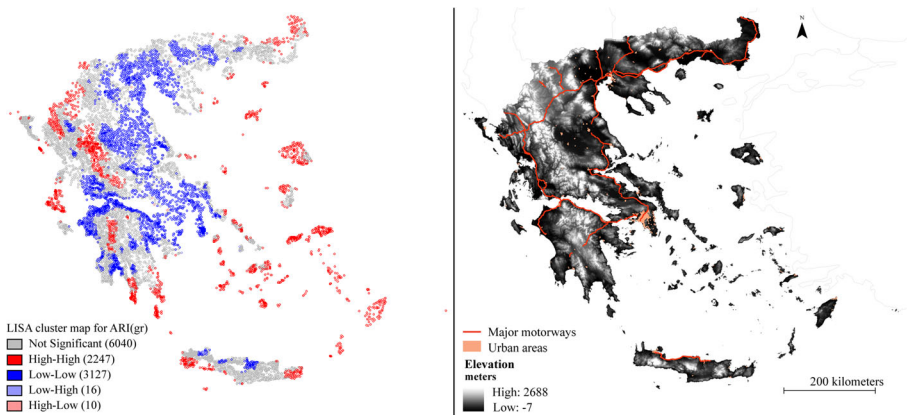
Table 5 shows the spatial dependence tests, OLS and spatial regressions for ARI(gr) and the various socioeconomic variables. The analysis has been made for two sample areas (national and mainland), since preliminary tests revealed strong deviations for the insular space. Both Moran's I and Robust LM (Lagrange Multiplier) tests suggest high spatial dependence for the selected regressions especially for income and unleaded95 price. Spatial regression is performed with the error or the lag model according to the results of the Robust LM tests. If both are highly significant, the lag model is preferred. At some level, remoteness or inaccessibility seems to affect all the chosen variables although extensive spatial disparities are observed.

It is rather clear that removing the islands from the data reduces the spatial dependence of the regressions. Both Moran's I and Robust LM significance are lower, while OLS regressions'  $R^2$  are higher (except for the unleaded95 price),



**Fig. 5** Univariate local Moran's I for ARI(gr) index. The value of 0.92 suggests a very high local spatial autocorrelation for the index

revealing that the islands do not follow the inequalities caused by remoteness as much as in mainland. This conclusion can be supported by the tourism activity of Greek islands, something that does not apply for rural mainland Greece. The exception of the unleaded95 price is partly caused by the high transportation cost of fuels to the islands, although fuel transport in Greece is rarely higher than €0.05/l, or more than 3% of the mean price for 2012. The very high price for Remote and Very Remote areas (+7%, Table 6) is mainly attributed to lower market competitiveness, due to the less and more dispersed gas stations.



**Fig. 6** LISA cluster map for ARI(gr). Clusters with high values are located in West mountainous Greece and islands, while low valued clusters can be found mainly in East mainland, along the major motorways and large urban centres

**Table 5** Spatial dependence tests, OLS and spatial regression of  $ARI(gr)$  as covariance and various socioeconomic data as dependent variables for two sample areas: National and Mainland

Dependent variable	Sample area <sup>a</sup>	Spatial dependence diagnostics				R <sup>2</sup>		Spatial lag/error		ARL(gr)	
		Moran's I	Robust LM (lag) p	Robust LM (error) p	OLS	Spatial lag/error	Coef.	p	Coef.	p	
Percentage of households without internet connection	N	0.62	0.01	0.00	0.06	0.51	0.65	0.00	0.008	0.00	
	M	0.50	0.37	0.00	0.30	0.58	0.63	0.00	0.04	0.00	
Percentage of population over 50 years of age	N	0.47	0.82	0.00	0.07	0.39	0.58	0.00	0.02	0.00	
	M	0.35	0.21	0.00	0.24	0.41	0.49	0.00	0.03	0.00	
Average household income	N	0.75	0.05	0.00	0.03	0.76	0.89	0.00	-36.5	0.00	
	M	0.68	0.00	0.00	0.17	0.74	0.85	0.00	-120.3	0.00	
Price of Unleaded95 petrol gas	N	0.74	0.00	0.00	0.22	0.82	0.89	0.00	0.001	0.00	
	M	0.67	0.00	0.00	0.09	0.72	0.86	0.00	0.003	0.00	
Percentage of population over 30 with higher education	N	0.47	0.95	0.00	0.03	0.36	0.56	0.00	-0.005	0.00	
	M	0.44	0.02	0.00	0.12	0.39	0.54	0.00	-0.006	0.00	

Spatial regression R<sup>2</sup> for lag or error is chosen according to the Robust LM (Lagrange Multiplier) lag or error significance (>0.05) where lag is preferred over error in case of both being significant

<sup>a</sup> Sample area is National (N) or Mainland (M)



**Table 6** Comparison of average household income and Unleaded95 price in each accessibility/remoteness class for two sample areas (National and Mainland)

Sample area	National		Mainland	
	Average household income	Average unleaded95 price	Average household income	Average unleaded95 price
Highly accessible	16,678 €	1.77 €	16,664 €	1.77 €
Accessible	14,911 €	1.80 €	14,567 €	1.79 €
Moderate accessible	14,584 €	1.82 €	13,856 €	1.80 €
Remote	15,080 €	1.84 €	13,140 €	1.81 €
Very remote	17,019 €	1.91 €	12,201 €	1.80 €

For the income, the differences in OLS regressions and spatial dependence tests for national and mainland level indicating a strong variation for the islands. Indeed, average household income is much higher in most of the Greek islands compared with rural mainland, an outcome of the heavy tourism industry. For the mainland, correlation of income with the index is stronger and remoteness negatively affects income (Table 5). Specifically, income is almost 35% lower in the Very Remote class compared to the Highly Accessible class (Table 6).

Regarding the human capital variables, population over 50 and population over 30 with higher education are increasing and decreasing with remoteness respectively (Tables 5 and 7). This implies that young people abandon remote rural areas and, in a certain degree, there is a less need for special skills in remote regions. Rural areas in Greece are mostly agriculture oriented and there is little variety in development plans to absorb people with higher education. These correlations are stronger in the case of the mainland. Supposedly, islands may still keep a percentage of young or people with special skills, even though they are remote, since job opportunities are favourable.

Lastly, internet availability in households seems to decrease with remoteness. This is a major issue since such infrastructures can play an important role in the alleviation of spatial peripherality (Copus 2001). The variations for mainland and national level are also present in this case, probably because of tourism that renders internet a prerequisite in islands. In contrast, households without internet connection in mainland exceed 95% for the Remote regions (Table 7).

**Table 7** Percentages of demographic and housing data in each ARI(gr) class for mainland Greece

ARI(gr) classes	Percentage of households without internet connection	Percentage of population over 50 years of age	Percentage of population over 30 with higher education
Highly accessible	52.49%	37.36%	22.84%
Accessible	75.50%	45.45%	10.35%
Moderate accessible	83.49%	52.20%	9.03%
Remote	96.37%	63.38%	5.13%
Very remote	75.11%	56.43%	8.33%

Very Remote regions do not follow the increasing or decreasing pattern of the rest regions mainly because of the small sample of Very Remote areas in mainland Greece

## Discussion and Conclusions

Inspired from ARIA, we have developed ARI(gr), an accessibility/remoteness index for Greece, with the required modifications to cover the very important differences between the two countries (e.g. area-population ratio, population distribution, insular space etc.). The modifications have taken place in two major areas. Firstly, an original work was required to classify the settlements of Greece into service centres. Secondly, given the complex insular space of Greece, a new methodology concerning the weighted sea route distance has been introduced. ARIA encompasses some elements that were useful for this study, but the general modifications could be similarly applied to other accessibility models given the localization of the study area's geographical characteristics in the two major components of gravity-based accessibility models. It should be noted that the use of a ratio in the impedance function is useful for readjusting the model to a different study area, however, the model cannot be used to compare the study areas in terms of accessibility.

Classification of settlements to service centres has been made by population size, which is supported by the strong correlation found between population size and basic services (health and education). The classification has revealed a distinct separation of Athens and Thessaloniki in a different scale than the rest of the large cities, with a clear precedence for Athens. As reference, the service centres classification in Australia have produced more than 10 major cities as the higher service centres in a single category (note that population of Australia is only twice that of Greece). The dominion of Athens over the rest of the large cities has also been reinforced by other evidence, like the connection between most of the islands and motorways. There are many evidence supporting that the conducted service centre classification reflects a broader view of human activities and not only the examined services.

Weighted distance for sea routes has been a significant addition regarding the Greek insular space. While sea travel presents obvious difficulties compared with land, it is daily routine for many people in Greece. Connections from the islands and coastal areas to large service centres are crucial for the inhabitants, especially in winter where ferry itineraries are significantly reduced. Thus, a new spatial-temporal equation that includes ferry itineraries in the distance ratio has been introduced. Hence, it is possible to capture specific transportation difficulties that arise in the islands and coastal areas, rather than generalise the sea travel impedance.

ARI(gr) produces representative accessibility/remoteness measurements for every settlement in Greece. The results are visually confirmed on the map representation of the index, creating well-defined clusters that can be empirically matched with the geographical characteristics of Greece. For instance, it is found that the majority of the small islands are the most remote places in Greece (Very Remote category), followed by the mountain areas and larger islands (Remote category). The index has high spatial autocorrelation (Moran's  $I = 0.92$ ), while the LISA cluster map covers in detail certain large geographical entities of known high (urban agglomerations and major motorways) or low (mountains and islands) accessibility. Additionally, the sensitivity analysis has shown that the model reacts accurately to changes in network infrastructures, capturing effectively the spatial differentiations. From an operational point of view, the adjustment of the components of the model (e.g. network

infrastructures) can generate new accessibility maps of the study area for assisting decision making and planning.

Several demographic, economic and infrastructure related parameters have been tested with ARI(gr), proving strong relation between accessibility/remoteness and critical socioeconomic characteristics in both the aggregated results for the ARI(gr) discrete categories, as well as in several OLS and spatial regressions. More specifically, population age distribution is strongly related to the accessibility of a place, and in remote regions ageing population holds a large portion that can exceed 60%. In addition, remote regions have a lower percentage of people over 30 with college or university degree, indicating issues in job opportunities and activity. Accessibility and development prospects in remote regions form a vicious circle. Inaccessibility (e.g. because of a poor network) affects labour supply and demand, as well as the access to basic health and education services. This leads to population loss following diminished job opportunities and needs for services that reduce the activity of a place and, thus, its accessibility. Fuel prices are much higher in remote regions throughout the whole of Greece. Almost a 7% increase has been observed for Unleaded95 petrol fuel in Very Remote regions. On the other hand, income is related to remoteness mostly in mainland, where a 35% drop is present from the highest to the lowest accessibility class. Lastly, households without internet connection have been found to increase in remote regions of mainland (reaching more than 95% in Remote areas), a case that is not evident in islands probably because of the tourism activity. Except for the fuel prices, all the other variables are strongly correlated with accessibility and mostly in mainland. The spatial analysis confirms that the islands do not follow the patterns of the mainland regarding accessibility and its impact in human capital, economy and infrastructures. Tourism industry in Greek islands helped to alleviate the deprivation that is apparent in most parts of rural mainland Greece. Correlations vary from very weak to strong, but it is to be expected since an accessibility index cannot, on its own, fully explain complex socioeconomic distributions in space. However, this study shows that accessibility can act as an additional evaluation tool to redirect policies for spatial equity.

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**Compliance with ethical standards**

**Conflict of Interest** The authors declare that they have no conflict of interest.

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