Determining the changes in commuting after the Ionian Motorway's construction

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Abstract
Commuting refers to the act of daily intercity traveling for employment purposes and constitutes a multidimensional phenomenon that is determined by a set of socioeconomic and geopolitical factors. This article studies how the commuting phenomenon is affected by changes in transport infrastructures and, in particular, after the construction of the Ionian Motorway that suggests one of the biggest infrastructure-works of the modern history at the West Greece and Epirus. A multi-regressive methodological framework is constructed for the analysis of commuting flows, applying three different versions of linear and generalized linear regression models, where the significant predictor variables elected per model are compared and found to converge into a single Newtonian gravity model. Finally, this paper estimates and illustrates the changes of the Ionian Motorway's construction, based on the commuting model that was constructed at the multi-regressive analysis.

Keywords: Commuting, Ionian Motorway, Transportation, Urban development

JEL classification: R40, R42, R49

Introduction

At the last decades, the limits of urban space have been particular indiscernible. The upgrade of the transportation infrastructures and of transportation networks, especially this of distant regions, is an important factor that promotes regional growth, but it also strengthens the diffusion of the urban activities into a wider range (Polyzos, 2011; Polyzos et al., 2013).

The quality of the interregional infrastructures constitutes a basic priority for the Regional Policy, in order to promote the development of the economically isolated regions (Polyzos, 2011). Within the last fifteen-year period, the most important motorways have been programmed and constructed in Greece, among which is the construction of the Ionian Motorway. The trajectory of the Ionian Motorway crosses the less developed Regions of Western Greece and Epirus, which are expected to improve their accessibility and their position in spatial competition, both in national and in international scale.

The construction of the Ionian Motorway is expected to induce a set of socioeconomic changes to the regional economy of the West Greece, among which is the determinative factors of the commuting (Polyzos et al., 2013; Tsiotas and Polyzos, 2013a) phenomenon. Commuting is generally the act of daily intercity traveling for employment purposes and it suggests a multivariate phenomenon in Regional Science, which is determined by social, economic, geographic and political factors (Polyzos et al., 2013). Last years, both the number of commuters and the average distance travelled by workers are been progressively increasing in most developed countries.

The basic attributes of commuting

Commuting is a diachronic and not a modern phenomenon and it is as old as the labor, in the form which was presented in the organized societies. Nevertheless, this phenomenon has attained a modern aspect, due to the evolution of transportation in the meta-industrialization period.

Initially, until the 19th century, the workers were usually choosing to reside near their works, so as to commute on foot in relatively short time, since they were being submitted to transportation mode and infrastructure constraints that describe the pre-industrialization era (Myers, 1997).

Today, commuting constitutes a daily act for a significant part of workers, which use different modes and cover a great variety of distances, in order to go to their work. Simultaneously, due to the technological evolution, commuting acquired multivariate characteristics that set its study quite complicated (Polyzos et al., 2013).

The basic attributes of commuting (Myers, 1997) are described in brief at the following subsections.

Mode of Commuting

This is one of the major determinative factors of commuting, which is diachronically related to the level of the technological evolution. Commuting modes that are diachronically met are:

- *Modes based on animal force*, as wheeled animal cabs and riding animals. Such modes were used widely in the past and are met today only in the developing countries.
- *Modes based on human force*: The two most popular modes (internationally) in this category are walking and bicycle, serving medium single distances within 5-10km.
- *Marine modes*: This way of transportation is met in coastal, lakeside and riverside countries and constitutes a functional and secure mode of traveling, allowing the economic interaction among island and continental regions.
- *Railway modes*: This category includes the railway, the suburban and underground railways and also the tram. Railways are widespread modes of traveling, which are recently used by more and more workers. They refer to an economic, reliable and fast way of commuting covering small and moderate distances.

- *Road network modes*: This category includes private and public cars, motorcycles, urban buses and trolleybus. These modes are equivalently capable with the railway modes, in covering moderate up to big distances, but they are more flexible and allow direct access to the place of work.
- *Combined modes*: This category refers to any combination between two or more of the previous categories. Despite that this category is not the rule describing commuting it constitutes the future bet for developing the concept of sustainable commuting.

Direction of commuting
According to Green and Meyer (1997), the direction of commuting is divided in the following categories:

- *Within the limits of the urban core* (*intra commuting*): It is the most populated category, concerning commuters that reside and work inside the limits of the urban core. All possible commuting modes are used in this category.
- *Into an urban center* (*ongoing commuting*): This category includes workers that commute into an urban center and live either in the suburbs (*urban-urban commuters*) or in the wider peri-urban zone surrounding the urban concentration (*rural-urban commuters*). Flows of this category are directed into the wider business center of the city or, in polycentric cases, into separate centers. All possible commuting modes are also used in this category.
- *From an urban core to the region* (*outgoing commuting*): This category describes commuters that reside within the limits of a city and daily travel either into in the outskirts (*urban-rural commuters*) or into neighbor cities (*urban-urban commuters*). This category is characteristic for the case of Greece, where the phenomenon of house-ownership (Polyzos et al., 2012) does not allow workers to change their residence according to the place of their work. Transportation modes covering moderate and large distances are used in this category.
- *Outside the urban core* (*rural commuting*): This category is divided into two subcategories, the first describing cases of commuting from a rural region into another (*rural-rural commuters*) and the second describing commutes within the limits of a rural region (*intra-rural commuters*).

Commuting Distance
Commuting distance constitutes an important factor of commuting, because it illustrates the spatial impedance (Tsiotas and Polyzos, 2013a) of the commuting trip, which is expressed in terms of monetary cost. An empirical classification of the commuting distance is (Polyzos et al., 2013):

- *Small Distance Commuting*: Covered distances of this category usually lie within the range 5-10km. The places of residence and work are within the administrative limits of the municipal unit. The main means of locomotion met in this category are walking, bicycle, modes of mass transport and private vehicles.
- *Medium Distance Commuting*: Distances of this category usually lie within the range of the municipality’s administrative limits, where the places of residence and work are not direct neighbors. Commuters of this category often use rail modes or the road network. The cost of commuting is important, but not particularly increased.

- *Large Distance Commuting*: It usually concerns cases of distant destinations, most of them interregional, lasting over 90 minutes per direction. Usual modes of transportation in this category are rail or road network and the transportation cost is quite increased.

Duration of travel
The duration of travel is an important factor of commuting, mainly depending on the traffic conditions, on the total distance and on the transportation mode. The duration of travel is classified into the following categories (Hamilton and Roell, 1982):

- *Short-time commuting*: Includes trips lasting 20-30 minutes per direction, which depend on the covered distance (small), on the transportation mode (fast) and on circulative conditions (good).
- *Medium-time commuting*: This category includes trips lasting 40-60 minutes and corresponds to the case of *Medium Distance Commuting*.
- *Long-time commuting*: Includes trips exceeding 90 minutes per direction and corresponds to the case of *Large Distance Commuting*. This category includes infrequent and few cases that usually refer to interregional commutes.

Travel cost
The travel or transportation cost of commuting is a multivariate factor that depends on a variety of components. Most of these components can be classified into the next categories:
- *Monetary cost*, referring to the ticket cost or to the fuel and vehicle’s maintenance cost of the commuting trip. This cost generally concerns the economic impact of the commuting act on the commuter (Hamilton, 1989).
- *Non monetary cost*, referring to non economic impacts that affect the physical and mental health of the commuter, as also their relations with friends or the family. The non monetary cost of commuting and, more generally, the satisfaction and the quality of life are directly related to the duration of the transportation travel (Stutzer and Frey, 2008).

The Ionian Motorway

The Ionian Motorway constitutes a transportation work of major national economic, developmental and social importance, which is included among the most important transportation infrastructure works that have been ever constructed in the modern history of Greece, along with the *Egnatia Motorway*, the *National Motorway Patras-Athens-Thesalonikis-Evzonoi* (*PATHE*) and the *Rio-Antirrio* conjunction. The Ionian Motorway is a transportation infrastructure work that is currently being constructed and it hasn’t been finished yet.

The Ionian Motorway is planned to have about 375km length, referring to the third in ranking longest motorway of the country, after the *PATHE* and the *Egnatia Motorway*. The termination of this work is expected to provide new developmental dynamics to the regions of the West Greece and Epirus, since it crosses 3 regions, 7 prefectures and 21 municipalities. The route of the Ionian Motorway is shown at figure 1.

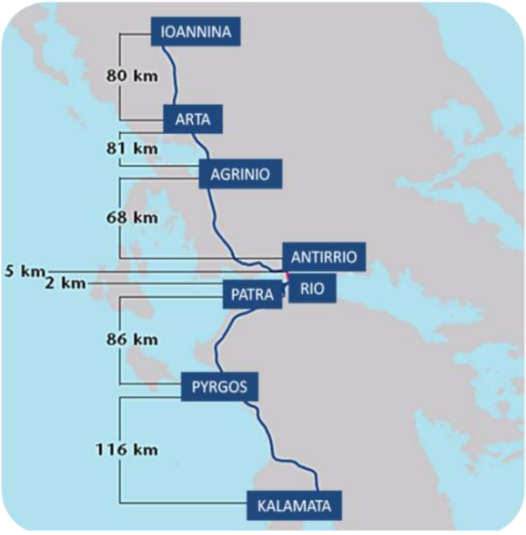

Figure 1: The route of the Ionian Highway

The Ionian Motorway will connect along its path 9 urban centers and 11 ports, where it is expected to promote their local economies. The budget of this work is around 1.3 billion euro (€) and its funding will be conducted under the state of Private-Public Partnership works (PPP's), where the participation of the Public reaches the 25%.
This research is driven by the rationale that changes in the transportation infrastructures have direct or indirect impacts on the surrounding socioeconomic framework and, under this rationale, it particularly studies how the commuting phenomenon is affected by such changes elected after the termination of the Ionian Motorway's construction.

The remainder of this article is organized as follows: Section 2 presents the methodological framework used in the analysis and the available data. Section 3 illustrates the results of the analysis and their interpretation and, finally, at Section 4 conclusions are given.

Methodology and Data

Study Area and Data

The study area of this paper constitutes a directed spatial network (Barthelemy, 2012; Tsiotas and Polyzos, 2013a) including 14 interacting cities of the northern half of the Ionian Motorway (*Ioannina*, *Dodoni*, *Zeros*, *Arta*, *George Karaeskakis*, *Nikolaos Skoufas*, *Preveza*, *Vonitsa*, *Amphilochea*, *Xeromero*, *Agrinio*, *Thermos*, *Nafpaktia* and *Mesologgi*), as it is shown in figure 2.

The study area is limited to the northern half of the Ionian Motorway's length, mainly due to the availability of the data. This spatial constraint does not undermine the validity of this study, since the methodological framework used in this paper is based on techniques of approved applicability and generality (Norusis, 2004; Tsiotas and Polyzos, 2013b).

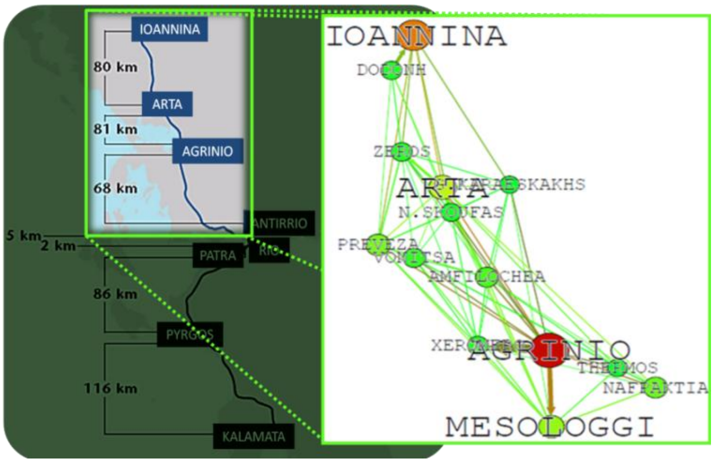

Figure 2: The study area of the analysis

The methodological framework

The methodology used in this study is based on the general model of interregional interaction (Polyzos, 2011), as it is shown in relation (1).

$$Y_{ij} = f(X_1, X_2, \ldots, X_n) = a_0 \prod_{i=1}^{n} X_i^{ai} \quad (1)$$

where:

Y_{ij} = Is the commuting interaction, i.e. the number of commuters between regions i and j.

X_i = Are the factors determining the commuting interaction

The model of relation (1) constitutes a generalization of the gravity model (de Grange et al, 2011; Tsiotas and Polyzos, 2013b), which is often used for the analysis of intra-regional and interregional flows. In order to degrade the difficulty of the solution of relation (1) and to use linear regression fitting techniques (Norusis, 2004), a logarithmic transformation ln$f(x)$ is applied to the model of relation (1), according to relation (2).

$$\ln Y = \ln a_0 + \sum_n a_i \ln(X_i) \quad (2)$$

The conceptual basis of the methodological framework used in this paper concerns first estimating an optimum quantification for the model of relation (2) and then calculating the changes induced to the response variable, according to the mathematical formula of the optimum model.

The methodological framework of this study consists of three steps, as it is shown in figure 3. This framework constitutes a multi-regressive empirical approach that applies different versions of linear and generalized linear regression models, in order to compare the results and produce a synthetic optimum model.

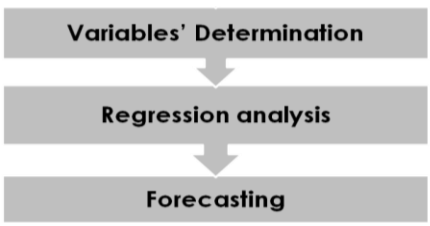

Figure 3: The three-step methodological framework of this study

Each step of the methodological framework is described in brief at the following sub-sections.

Step#1: Variables' Determination

Selecting the variables that participate in a quantitative model is a crucial procedure for the determination ability and the effectiveness of the model (Norusis, 2004; Polyzos et al., 2013). Useful consultants in this procedure are the existing literature studying such cases and the experience of the researchers.

Table 1 shows the variables participating in the analysis, which are drafted from the existing literature (Hamilton και Roell, 1982; Green and Meyer, 1997; Myers, 1997; Polyzos, 2011; Polyzos et al., 2013) and are briefly described in the next paragraphs.

Table 1: Variables participating in the analysis

Variable	Symbol	Description	Unit	Source
		RESPONSE VARIABLE		
Commuting Flows	Y	The number of commuters	Number of people/ Population	(Duquenne, 2009)
		PREDICTOR VARIABLES		
Mass of Origin	Mi (X_1)	The number of commuters that originate from a city	Population	(ELSTAT, 2011)
Mass of Destination	Mj (X_2)	The number of commuters that arrive to a city	Population	(ELSTAT, 2011)
Spacetime	St (X_3)	Travel time for conducting a single commuting trip	Minutes	Unpublished Data from TERNA SA
Secondary Sector's Participation	BSEC (X_4)	The participation of the B΄ Sector in formulating the GDP of the city of origin	Non-dimensional number	(ELSTAT, 2011)
Tertiary Sector's Participation	CSEC (X_5)	The participation of the B΄ Sector in formulating the GDP of the city of origin	Non-dimensional number	(ELSTAT, 2011)
Population Change	VAR (X_6)	The fraction $\frac{POP_{city\ of\ origin}\_2011}{POP_{city\ of\ origin}\_2001}$	Non-dimensional number	(ELSTAT, 2011; ELSTAT, 2001)

Population-Mass of Origin (Mi)

Population masses usually produce important flows originated from and directed to the urban centers (Polyzos, 2011). As the size of a city grows, the intra-commuting flows turn greater, implying that workers choose less often to move away from their city of residence. Simultaneously, the commuting flows originating from neighbor cities with less population size are strengthened.

However, this continuous flow attraction sometimes saturates, creating reversed flows to neighbor cities, even to those that are less developed. In general, the increase of population is expected to be positively related to the increase of the commuting flows.

Population-Mass of Destination (Mj)

Regions with big population sizes are expected to attract high commuting flows. This is due to the existence of high possibility for finding a work in such regions, even in cases that this presupposes executing great distance commuting.

Spacetime (St)
The development and the quality of the transportation infrastructures in a city obviously affect the locomotion. When transportation is easier, people are more willing to search for a job, according to their expectations, outside their city of residence.

Secondary sector's participation of the city of origin (BSEC)
When the secondary sector in a city is highly developed, then the employment opportunities it is more possible to be increased. Consequently, the existence of industrial areas, parks or other manufacturing infrastructures in the city of origin tend to produce commuting flows originating from the urban core to the countryside, since such facilities are mainly located in the countryside (outgoing commuting), but they also produce flows originating from neighbor cities that have less developed secondary sector and consequently decreased employment opportunities (rural commuting).

Tertiary sector's participation of the city of origin (CSEC)

The biggest part of cities' economy is based on the tertiary sector (Polyzos et al., 2013). When the tertiary sector in a city is highly developed, then the employment opportunities in this city are also more possible to be increased. This reduces the outgoing and rural commuting leaks, since the tertiary sector's facilities and activities are mainly located within the urban core.

Population's change of the city of origin
The population's change of a city constitutes an also important factor for the determination of level of growth and of the prosperity of the city, fact that proportionally affects the employment opportunities. Positive changes in the population of a city (as they are captured by the differences POP_{2001}-POP_{2011}) are more likely to produce incoming rather than outgoing commuting flows.

Step#2: Regression Analysis
At the second step of the methodology, a multi-regression analysis is applied to the general interregional interaction model, in order to detect common regularities and to synthesize a universal regression model of general utility. This approach applies three different versions of linear and generalized linear regression models and, in particular, the *Simple Linear* (*SLR*), the *Backward Elimination Method* (*BEM*) and the *ordinal regression* (*OR*) versions.

The *Simple Linear Regression Model* (*SLR*) produces a linear approximation that is best fitted on the available data, according to the relation (3), where *Y* represents the response variable, *Xi* the predictors and *c* the constant.

$$Y = \sum_{i=1}^{6} b_i \cdot X_i + c = b_1 \cdot X_1 + b_2 \cdot X_2 + ... + b_6 \cdot X_6 + c \qquad (3)$$

The algorithm used by the *SLR* is the *Ordinary Least Squares* method (OLS), where the square differences between the observed $F(x)$ and the theoretical $\hat{F}(x)$ distributions $\left(\hat{F}(x_i) - F(x_i)\right)^2$ are minimized (Norusis, 2004).

Next, the *Backward Elimination Method* (BEM) (Norusis, 2004; Hastie et al., 2009) constitutes a version of the SLR, which starts with the full model, including all chosen predictors, and provides a sequence of models Y_k, where the most insignificant predictors are removed in succession, one per loop, among these that have statistical significance (*p*-value) $p>0.1$. Given the set of dependent variables $X_n=\{X_1, X_2, \ldots, X_n\}$ then the sequence of the BEM dependent variables $(Y_k)_{k>0}$ is described by relation (4).

$$\begin{cases} (Y_k)_{k\in\{1,\ldots,n\}\subseteq IN} \\ Y_k = \sum_{i=1}^{n-k+1} a_i \cdot X_i + c_k \\ \mathbf{X}_n = \{X_1, X_2, \ldots, X_n\} \\ X_i \in \mathbf{X}_{n-k+1} \\ \mathbf{X}_{n-k} = \mathbf{X}_{n-k+1} - \{X_p\} \\ X_p \in \mathbf{X}_{n-k+1} : P[a(X_p) = 0] = \max\{P[a_i = 0] \geq 0, 1\} \end{cases} \quad (4)$$

In the BEM, the standardized coefficients calculated from this process indicate the level of participation of each predictor variable to the model (Norusis, 2004; Hastie et al., 2009).

The *Ordinal Regression model* (*OR*) consists of three components, the *location*, the *scale* component and the *link function*. The *Location Component* includes the classical regression part, with the predictor variables and their coefficients. This component contributes to the calculation of probabilities for each category of the response variable. The *Scale Component* constitutes a modification of the simple case model, so as to take under consideration the differences of variation between the independent variables. Finally, the *Link Function* suggests a transformation of the cumulative probabilities of the dependent variable, so as to achieve optimum fitting results. The link function depends from the distribution of the response variable.

The mathematical formula of the ordinal regression model is shown at relation (5) (McCullagh, 1980; McCullagh and Nelder, 1989; Norusis, 2004),

$$link(\gamma_{ij}) = \theta_j - \sum_{k=1}^{p} b_k X_{ik} \Rightarrow link(\ln(Y_{ij})) = \theta_j - \sum_{k=1}^{p} a_k \ln(X_{ik}) \quad (5)$$

where:

- *link*() = is the link function (index *j* refers to each dependent variable's category).
- γ_{ij} = expresses the cumulative probability of the j^{th} category for the i^{th} case (in the certain case the response variable is categorical and can receive physical values between 1 to 4)
- θ_j = the regression's constant terms (thresholds) for each category
- b_k = are the coefficients of the predictor variables (location components, that are estimated by the maximum likelihood method)
- X_k = are the *k* independent variables
- $z_{i1}...z_{im}$ = are the *m* defining variables for the scale component (that are being chosen between the predictor variables *X*)
- $t_1...t_m$ = are the coefficients of the scale component's variables

In order to meet the standards for applying the ordinal regression model on the available commuting data, the scale response variable is transformed into an ordinal one, by dividing the range of its values into five classes of the same length. Following this treatment, the new response variable Y is an ordinal variable getting the values 1="very low", 2="low", 3="moderate", 4="high" and 5="very high" commuting flows.

Additionally, in order to take advantage of the fact that the ordinal regression analysis favors the treatment of both nominal (factor) and scale (covariates) variables (Norusis, 2004), due to its optimization algorithm that is based, instead on the OLS, on the maximum likelihood method, an extra nominal predictor variable is added in the model. This extra predictor constitutes a binary variable that represents the signal (+/-) of the difference between the populations of the city of origin minus this of the city of destination (for the year 2011), as it is defined in relation (6).

$$X_7 = sign\left(diff\_POP\right) = sign\left(POP_{origin} - POP_{destination}\right) = \\ = sign\left(Mi - Mj\right) = \begin{cases} "-" \equiv 0, \text{ if sign<0} \\ "+" \equiv 1, \text{ if sign>0} \end{cases} \quad (6)$$

The X_7 factor in the ordinal regression analysis is complementary to the variable X_6 that measures population changes just in the city of origin and it is expected to capture how differential population changes affect commuting flows.

According to the foregoing remarks, the construction of an ordinal regression model is process including three decision steps, one for determining the form of each component. The researcher using an ordinal regression model has to decide the form of all the three components and the existence or not of the scale component, which is optional to the model. The most common treatment for the scale component instructs not to include it in the model, unless the bare (location only-) model does not provide satisfactory results (Norusis, 2004; Polyzos et al., 2013), fact that stand for this case and thus the scale component is excluded from the analysis.

Finally, the step of choosing a proper link function depends on the distribution of the ordinal response variable (Norusis, 2004; Polyzos et al., 2013), which is found to describe categories with decreasing probability and thus the Negative Log-Log link function is selected in the model.

Step#3: Forecasting

At the final step of the methodology the predictions are made, based on the linear regression model as it is captured at the procedure described at the second step. Given the final regression model describing the commuting flows Y as a function of the predictor variables $Y=f(X_1,X_2,\dots,X_6)$, then the changes in the response variable dY are estimated according to relation (7).

$$\mathrm{d}Y = \frac{\partial f(X_1, X_2, \dots, X_6)}{\partial X_i}\,\mathrm{d}X_i \quad (7)$$

where

d = is the differential's operator

∂ = is the partial derivative's operator

Results and Discussion

The *model summaries* of the multi-regression analysis are shown in table 2, where we can observe that the coefficient of determination (R-square) both for the *SLR* and *BEM* models are satisfactory, being able to describe almost the 70% of the variation of the data (Norusis, 2004). In particular, the R-square of the SLR model interprets that this model is able to describe the 68.6% of the variation of the commuting data, while the R-square of the BEM optimum model, reached after the execution of four (4) loops, is able to respectively describe the 68.6% of the variation of the commuting data.

Regarding the *ordinal regression* model, we can see that its determination ability, illustrated by the values of the pseudo R-square coefficients, is also acceptable, ranging from 30-60%. The additional to the pseudo R-square information, provided in table 2, supports the satisfactory ability of determination of this OR model.

Table 2: Multi-regression model summaries and information

Linear Regression Model Summary

Linear Regression Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.828[a]	.686	.667	1.050087

a. Predictors: (Constant), VAR, Mj, St, Mi, BSEC, CSEC

BEM Model Summary

BEM Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.828[a]	.686	.667	1.050087
2	.827[b]	.684	.668	1.048427
3	.824[c]	.679	.667	1.050278
4	.824[d]	.679	.670	1.046710

a. Predictors: (Constant), VAR, Mj, St, Mi, BSEC, CSEC
b. Predictors: (Constant), VAR, Mj, St, Mi, CSEC
c. Predictors: (Constant), VAR, Mj, St, Mi
d. Predictors: (Constant), Mj, St, Mi

Ordinal Regression Model Fitting Information

Ordinal Regression Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	323.596			
Final	227.471	96.125	7	.000

Link function: Negative Log-log.

Ordinal Regression

Goodness-of-Fit

	Chi-Square	Df	Sig.
Pearson	388.262	433	.940
Deviance	227.471	433	1.000

Pseudo R-Square

Cox and Snell	.579
Nagelkerke	.613
McFadden	.297

Link function: Negative Log-log

Ordinal Regression Test of Parallel Lines[a]

Model	-2 Log	Chi-	df	Sig.

	Likelihood	Square		
Null Hypothesis	227.471			
General	213.326[b]	14.145[c]	21	.863

-The null hypothesis states that the location parameters (slope coefficients) are the same across response categories.
a. Link function: Negative Log-log.
b. The log-likelihood value cannot be further increased after maximum number of step-halving.
c. The Chi-Square statistic is computed based on the log-likelihood value of the last iteration of the general model. Validity of the test is uncertain.

In particular, the significant χ^2 (chi-square) statistic, shown in the ordinal regression model fitting information sub-table, indicates that the ordinal regression (final) model gives a significant improvement over the baseline (intercept-only) model. This implies that the model gives better predictions in comparison with a simple guess, based on the marginal probabilities for the outcome categories.

Next, the goodness-of-fit information sub-table tests whether the observed data are inconsistent to the fitted model. Both results of the Pearson's and Deviance test statistics imply that the data and the model predictions are similar (Norusis, 2004) and thus the ordinal regression model is described by a very high ability of determination. Finally, the test of parallel lines is applied for location-only models and detects if the regression coefficients are equal for all corresponding outcome categories, implying that they lie on a set of parallel lines or planes (Norusis, 2004; Polyzos et al., 2013). The results of this test show that the improvements recorded for the general model are insignificant, implying that the ordinal regression model is described by the same parameters for each category, according to the null hypothesis' statement.

The next part of the analysis is the estimations of the regressions coefficients. The results for each one of the three examined regression models (*simple linear regression, backward elimination method, ordinal regression*) are shown in table 3. The estimates of the regression coefficients are shown in the (unstandardized and standardized) Beta ("B") columns and the scores of the t-statistic and the significance (Norusis, 2004), corresponding to each estimated coefficient, are shown in the last pair of columns.

Table 3: Estimates of the multi-regression models
Linear Regression Model

Linear Regression Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	T	Sig.
1	(Constant)	-8.733	3.136		-2.785	.006
	Mi	1.350	.240	.515	5.633	.000
	Mj	1.102	.151	.413	7.309	.000
	St	-2.367	.197	-.689	-12.030	.000
	BSEC	.570	.697	.084	.817	.416
	CSEC	-1.518	1.100	-.255	-1.380	.171
	VAR	3.312	2.310	.150	1.434	.155

a. Dependent Variable: Y

BEM Model

BEM Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
4	(Constant)	-11.401	2.399		-4.751	.000
	Mi	1.158	.146	.442	7.911	.000
	Mj	1.109	.150	.415	7.415	.000
	St	-2.291	.189	-.667	-12.104	.000

a. Dependent Variable: Y

Ordinal Regression Model

Ordinal Regression Model		Estimate B	Std. Error	Wald	df	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Threshold	[O=1]	9.342	4.145	5.078	1	.024	1.217	17.467
	[O=2]	10.560	4.176	6.394	1	.011	2.375	18.746
	[O=3]	12.174	4.211	8.358	1	.004	3.921	20.426
	[O=4]	14.096	4.233	11.087	1	.001	5.799	22.394
Location	Mi	1.617	.360	20.215	1	.000	.912	2.322
	Mj	.848	.260	10.640	1	.001	.339	1.358
	St	-2.608	.335	60.574	1	.000	-3.265	-1.951
	BSEC	-.635	.950	.447	1	.504	-2.496	1.227
	CSEC	-.676	1.450	.218	1	.641	-3.517	2.165
	VAR	3.215	3.188	1.017	1	.313	-3.034	9.464
	[SIGN=1]	-.863	.466	3.434	1	.064	-1.777	.050
	[SIGN=2]	0[a]			0			

Link function: Negative Log-log.
a. This parameter is set to zero because it is redundant.

In the sub-table of the Linear Regression Model (table 3), we can see the participation of each predictor variable to the model. According to this sub-table, the contribution of the predictors *BSEC*, *CSEC* and *VAR* is insignificant to the model. Nevertheless, within a 15-17% level of uncertainty, it seems that the *tertiary sector's participation of the city of origin* (*CSEC*) contributes negatively to the production of commuting flows, while the *population's change of the city of origin* (*VAR*) seems to have a positive contribution. These results accredit the theory, where cities with developed tertiary sector present fewer outgoing and rural commuting leaks, while positive changes in the population of a city are more likely to produce incoming rather than outgoing commuting flows.

The significant predictors shown in the sub-table of the Linear Regression Model (table 3) are exactly the same as the remaining predictors of the BEM Model (table 3), which are the *population of the city of origin* (Mi) and *destination* (Mj) and the *spacetime distance* (St). This observation, in conjunction with the numerical estimations, renders to the interregional interaction model of relation (1) a Newtonian (Serway, 1990) gravity structure, illustrating a straight analogy of the commuting flows to masses and an inverse analogy to the spatial impedance (Serway, 1990; Tsiotas and Polyzos, 2013a).

In accordance to the results of the SLR and BEM models are also the significant predictors of the ordinal regression model, as it is shown in table 3. This consistency seems also to be preserved in the signals of the (insignificant) predictor variables CSEC and VAR, fact that reinforces the previous ascertainment regarding the compliance with the theory. On the other hand, the signal of the independent variable *BSEC* does not correspond to this of the BEM model, but this observation cannot attain any interpretation, due to the existence of high level of uncertainty (sig_{SLR}=0.416, sig_{OR}=0.504).

Additional information, provided by the ordinal regression model, regards the performance of the extra variable (X_7≡SIGN) that is considered in this part of the analysis. According to the results of the OR sub-table (table 3), the signal of the population difference between the cities of origin and destination constitutes a significant factor to the OR model, lying under a negative analogy. This implies that outgoing commuting into destination cities of greater population is more likely to occur or, alternatively, that workers seek for a job and prefer to commute into cities that are more populated than their city of residence.

According to the foregoing multi-regression analysis, the tabulated results with the significant predictors of the SLR, BEM and OR regression models are shown in table 4.

Table 4: Tabulated results with the significant predictors of the multi-regression analysis

	SIMPLE LINEAR		BEM		ORDINAL	
Predictors	B	Sig.	B	Sig.	B	Sig.
(Constant)	-8.733	.006	-11.401	.000		
Mi	1.350	.000	1.158	.000	1.617	.000
Mj	1.102	.000	1.109	.000	.848	.001
St	-2.367	.000	-2.291	.000	-2.608	.000

a. Dependent Variable: Y=Commuters

The results of table 4 specialize the interregional interaction model of relation (1) into the formula of relation (8), where values in the symbol [*,*] denote an interval including the border values.

$$Y_{ij} = f(M_i, M_j, S_t) = \frac{1}{e^{[8.733,11.401]}} \cdot \frac{\left(M_i\right)^{[1.158,1.617]} \cdot \left(M_j\right)^{[0.848,1.109]}}{\left(S_t\right)^{[2.291,2.608]}} \sim k \cdot \frac{M_i \cdot M_j}{S_t^{\,2}} \qquad (8)$$

Relation (8) illustrates a discrete planetary (gravity) pattern, in accordance to the formula described by the Classic Newtonian Physics (Serway, 1990). This gravity interpretation elects the utility of the Econophysics' modeling (Tsiotas and Polyzos, 2013a) in the study of socioeconomic spatial systems, promoting the unifying school of thinking in the research of Regional Science.

Estimating the changes in commuting after the Ionian Motorway's construction

After the specialization of the model, shown in relation (8), the changes in commuting after the Ionian Motorway's construction are estimated according to relation (7), as it is shown in relation (9).

$$dY = \frac{\partial f(M_i, M_j, S_t)}{\partial X} dX, \text{ where } X = M_i, M_j, S_t \qquad (9)$$

Changes in commuting (dY) due to the Ionian Motorway's construction depend on the changes induced in the travel time S_t=f(infrastructure quality). According to this observation, relation (9) turns into relation (10).

$$dY = \frac{\partial f(M_i, M_j, S_t)}{\partial S_t} dS_t = \frac{\partial}{\partial S_t}\left(k \cdot \frac{M_i \cdot M_j}{S_t^{\ 2}}\right) dS_t = -\left(k' \cdot \frac{M_i \cdot M_j}{S_t^{\ 3}}\right) dS \qquad (10)$$

The changes in commuting, estimated according to relation (10) for each of the 14 cities that participated in the analysis, are illustrated in the map of figure 4, where the light yellow color describes cases before the construction of the Ionian Motorway and the dark color after the construction.

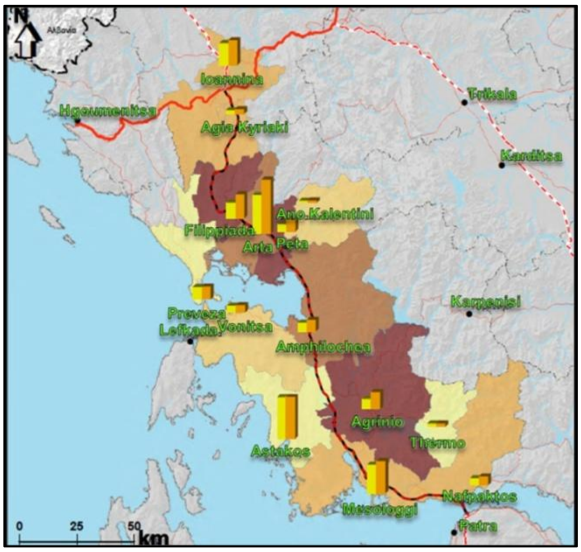

Figure 4: Number of commuters before (in light yellow) and after (in dark yellow) the construction of the Ionian Motorway.

Finally, the changes in the radius of the accessibility zones of commuting after the construction of the Ionian Motorway are presented in the Appendix. This interprets how more far the commuters of a given city are able to travel, due to the construction of the Ionian Motorway, while spending the same time in the commuting trip.

Conclusions

This paper constructed and applied a multi-regressive methodological framework for the determination of changes in commuting after the Ionian Motorway's construction. The rationale of this study is that changes in the transportation infrastructures have direct or indirect impacts on the surrounding socioeconomic framework, where commuting suggests a characteristic aspect involving societies, labor and space. Theoretical aspects of commuting were examined providing documentation for selecting the predictor variables that participated in the multi-regressive analysis.

The analysis generally verified the multivariate nature of the commuting phenomenon and, particularly, that commuting is a socioeconomic and spatial phenomenon that it can be described by a Newtonian gravity pattern, in accordance to the rules governing the planet systems.

In general, this paper elected the utility of the Econophysics' modeling in the study of socioeconomic spatial systems and the utility of quantitative spatial and socioeconomic analysis to the infrastructure planning and policy.

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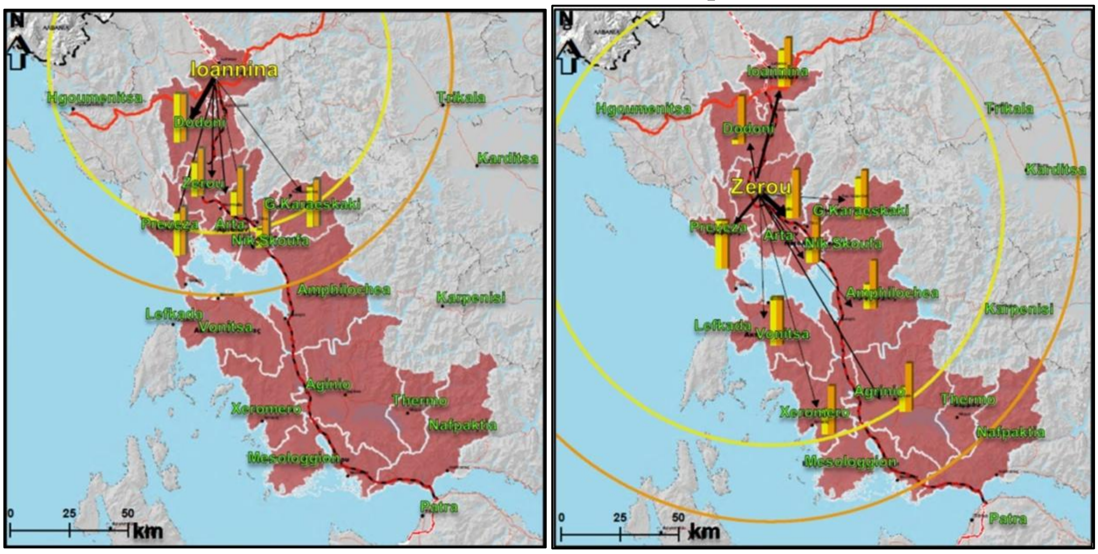
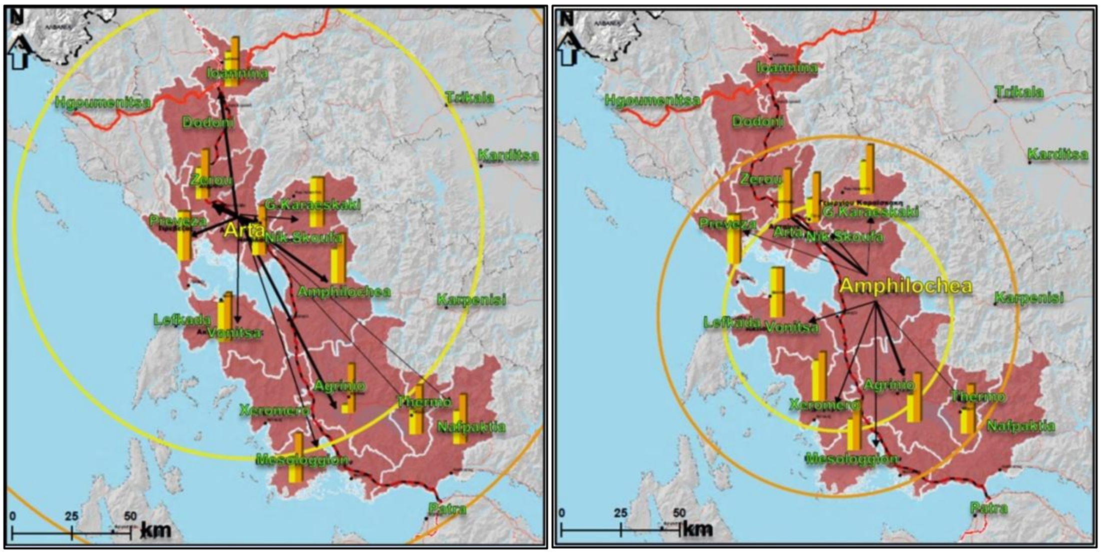
Appendix

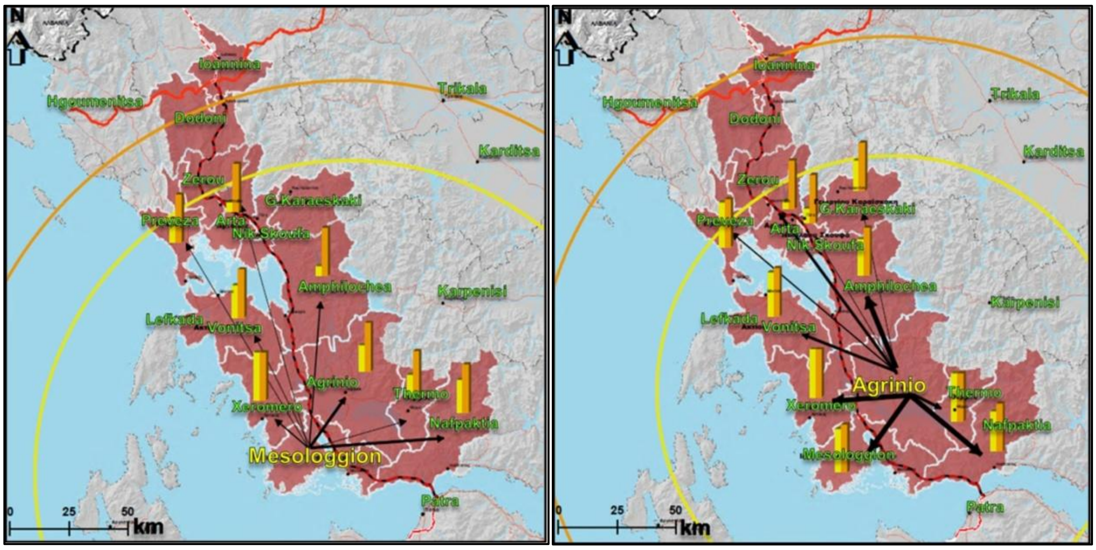
Estimated changes in the radius of the commuting accessibility zones, after the construction of the Ionian Motorway.



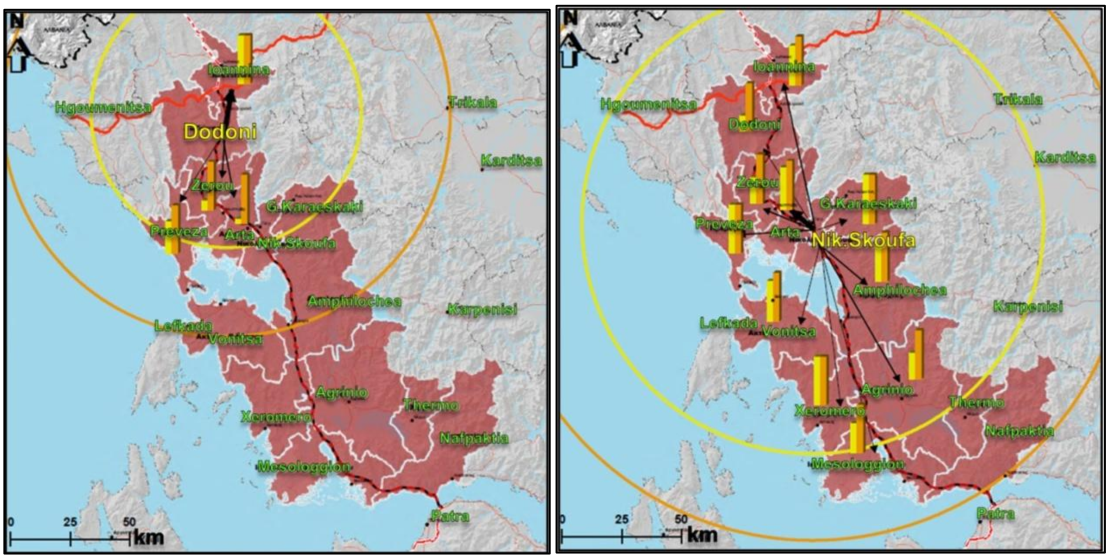
Cities: Ioannina & Zeros



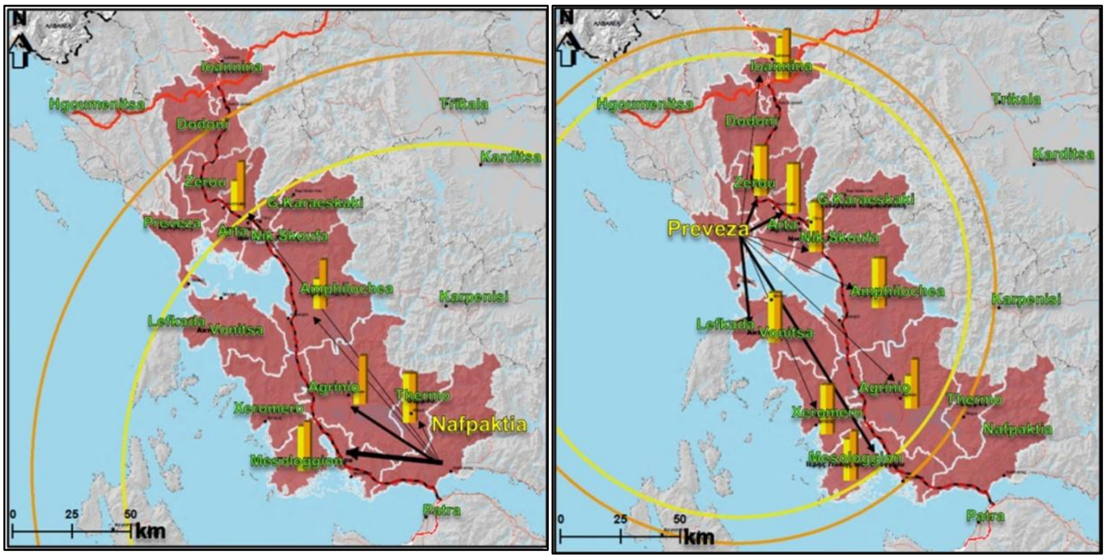
Cities: Arta & Amphilochea



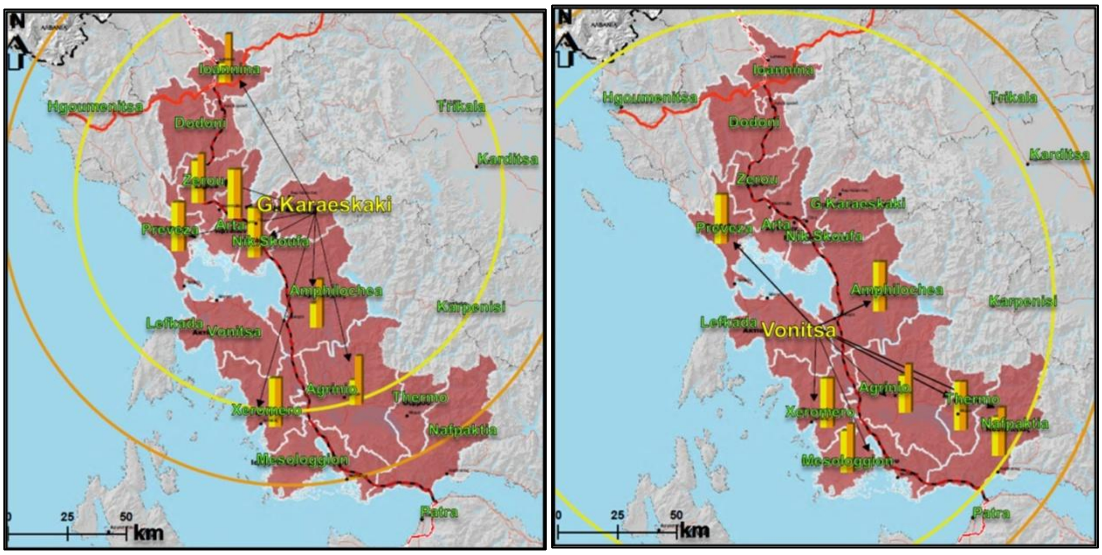
Cities: Mesologgion & Agrinio



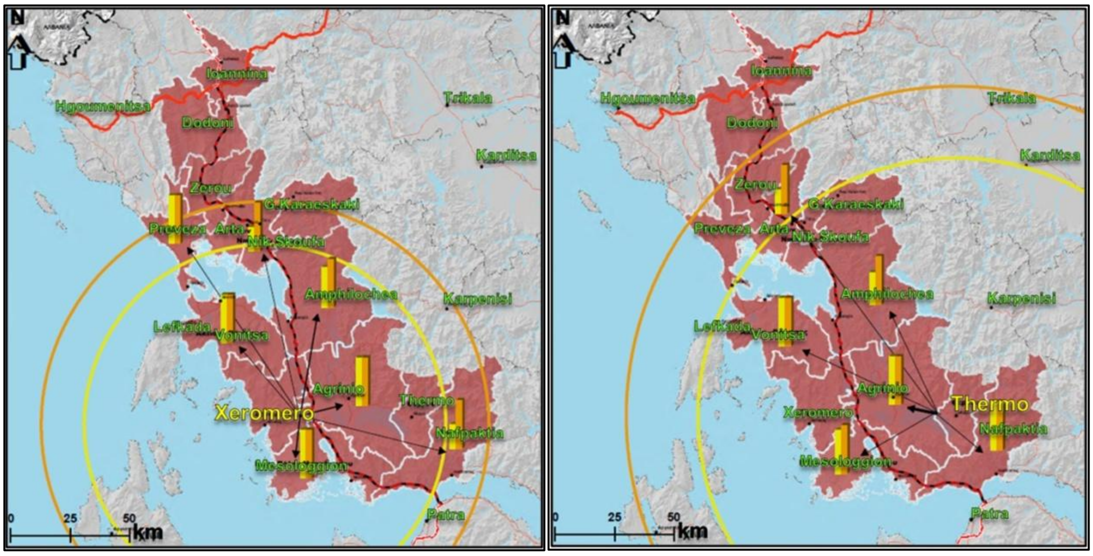
Cities: Dodoni & Nikolaos Skoufas



Cities: Nafpaktia & Preveza



Cities: George Karaeskakis & Vonitsa



Cities: Xeromero & Thermos