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Research Article

Determining the Driving Factors of Commuting: An Empirical Analysis from Greece

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Abstract

Commuting refers to the act of daily traveling, between two locations, for employment purposes and suggests a multidimensional phenomenon in Regional Science, which is determined by social, economic, geographic and political factors. This paper conducts initially a literal approach of the phenomenon and further proceeds to an empirical ordinal regression analysis for the spatial network consisting of two Greece regions (Thessaly and Sterea Hellas) that verifies the theoretical framework. The theoretical review contributes to the formulation of the independent (predictor) variables and generally to the construction of the ordinal regression model and the corresponding empirical approach, in order to specialize the theoretical framework to the Greek case and to recognize the spatial patterns that rule the commuting phenomenon. Some conclusions that are made, come to an agreement with the well established theories of gravity modeling, expanding city and binomial law and others elect an amount of interesting contradictions to the theoretical framework.

Keywords: Commuting, Ordinal Regression, Spatial Patterns, Spatial Network

1. Introduction

Labor location's attributes and its spatial distribution suggest diachronically significant parameters for the natural, social and structured environment, as well as for the regional economy (Veldkamp and Lambin, 2001; Muniz and Galindo, 2005). Consequently, the comprehension of the operative causes and the defining factors of the commuting phenomenon constitutes a considerable effort for the effective transportation infrastructures' planning (Renkow and Hoover, 2000; Evans et al., 2002; Van Ommeren and Rietveld, 2005).

The theoretical framework that describes the commuting phenomenon is synthetic, provided by different scientific sectors, such as Regional Economics, Political Economy, Sociology, Anthropography and Economic Geography. Through this theoretical background, three fundamental axes for the study of the commuting system are distinguished: the first concerns the *location behavior of the productive activities* (travel destination) (Beckmann and Thisse, 1987), the second regards *the urban land pricing and the residence cost* (travel origin) (Simson and Van der Veen, 1992) and the last refers to the *determining characteristics* of the commute (Noland, 1997; Susilo and Kitamura, 2008; Yeo and He, 2009). The theoretic matter of the first category contributes to the comprehension of the mechanism that creates a location for a labor activity (destination). The second category describes the attitude and the strategies that produce the residence location (origin). Finally, the third category studies traversal or intermediate matters, such as the means of commuting, the choice of direction, the volume of the trip and its duration.

Due to a microeconomic perspective, labor locations (which emerge from actions of enterprises) produce spatial potentials that synthesize, under a macroeconomic point of view, a *labor's location geography* (Dickinson, 1957; Dickinson, 1959). This geography constitutes an individual scientific field since 1909, when Weber introduced the *location - production model* that describes a mechanism of enterprises' installation placement. Later theories contribute supplementary to this model. For example, Marshall (1916) studied the comparative advantages of *labor's spatial coexistence* (Amarasekare, 2003) and its subsequent *interactions* (Smith and Slater, 1981), regarding destination locations. Also, the Hotelling's model (1929) (McCann, 2001) recognizes competing effects in agglomeration acts of enterprises (Polyzos, 2011).

After the war, Moses (1958) developed a model that describes the *alternations* that labor locations are submitted to *under substitution* (McCann, 2001). The theory of *poles of growth*, by Perroux and Boudeville (Kongstad, 1974), illustrates the sprawl effects of economic activities that generate new labor locations in scaling distances. Alonso's model of *urban land pricing* (1960), which was inspired from Vön Thünen's theory (Asami, 1990), studies the spatial structures of urban land uses, under the acts of land and infrastructures engagement. This model also includes other parameters, such as the environment quality and transportation cost of locomotion. Additionally, Van Ommeren and Fosgerau (2009) underlined the importance of transportation cost in the structure of urban shaping.

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Modern theories conduct a multi-parametric approach to the geography of labor locations. By that time, the *transportation cost* posses a significant meaning (Giuliano and Small, 1993; Glaeser and Kohlhase, 2003) that depends from the *travel stress* (Koslowsky et al., 1995), the *travel accident probability* (Ozbay et al., 2007; Nie et al., 2011), the *transportation alternatives* (Zegras, 1998; Murphy, 2009), the *route alternatives* (Liu and Nie, 2011) and the *spacetime cost* (Van Ommeren and Fosgerau, 2009). Other studies correlate *average commuting distance* (Cervero, 1996; Clark et al., 2003) with *productivity changes*, with employees' compensations and with enterprises profits (Van Ommeren and Rietveld, 2005).

The deepening commuting research led to the formulation of many types of models, such as *polycentric regions*, *gravity* and *expanding cities models*. Polycentric regions models (Gordon et al., 1989) apply a systemic approach to the spatial commuting patterns that interpret them as multi-core origin-destination networks. Gravity models (de Grange et al., 2011) study the existence of attractive or expelling spatial potentials, as an effect of regional population size, in accordance with the gravity potentials in Physics that result from mass interactions (Serway, 1990). The *expanding city* theories (Turner, 1985) interpret both population and occupation sprawl trends (Thurston and Yezer, 1994) under the perspectives of the *activities' structural polycentricity* and the *general sectorial division*. The use of individual means of transportation consists an era to the commuting evolution and growth, which reinforced labor decentralisation and urban sprawl (Glaeser and Kahn, 2004).

Therefore, the majority of the existing theoretical approaches for labor locomotion and commuting illustrate the spatial arrangement of new urban structures and uses, under the classification of four axes: *locomotions* (possibilities, means, transportation cost, accessibility), *welfare level* (modern models of life, preferences, welfare location, social values system), *economic framework* (evolutions in local and international level due to globalisation and to new economic geography of production and consumption) and *demographic forces* (regional and urban growth transformation). In this article, the theoretical defining factors of commuting are used as statistical variables in an empirical analysis with ordinal regression model.

This paper is organized as follows: Section 2 presents the methodological framework: the available data, the statistical model and its specialization for the commuting case. Section 3 proceeds to the ordinal regression analysis and provides result interpretation, under a spatial economic perspective. Finally, in section 4 some conclusions are given.

2. Methodological Framework

2.1. Data and Methodology

Commuting suggests a significant research field in Regional Science and, consequently, its driving factors (as size, direction, commuting flow, mean of transportation, time and distance) should be taken under consideration for the effective regional planning and policy making (Brueckner and Fansler, 1983; Van Ommeren et al., 2000). Of course, these factors are not totally a priori determined and their assessment must be a result of a profound scientific research. Nevertheless, commuting driving factors can be classified in three categories, depending on the *population's spatial distribution* (Brueckner, 2000; Glaeser and Kahn, 2004), on *urban economy's characteristics in the region of origin* (Lee and McDonald, 2003) and on *the quality of human potential* (Ory et al., 2004). This paper studies the volume (or size in terms of distance) of commuting in comparison with the most representative defining factors that suggest *economic*, *social* and *demographic* variables.

The Greek interregional commuting communication system, consisting of the capital cities of the prefectures belonging to the regions of *Thessaly* and *Sterea Hellas*, constitutes a spatial network that it can be modeled by a directed Graph $G(V,E)$, consisting of one bond component (Diestel 2005). Each Greek capital city P_i (i=1,…,9) is represented by a vertex or node ($P_i \rightarrow v_i$) $v_i \in G(V)$ and the commuting connections among pairs of nodes v_i and v_j ($i \neq j$=1,…,9) represents edges or links $e_{ij} \in G(E)$ that they are drawn as linear segments (figure 1). The interregional commuting network is both a node and edge weighted network (Tsiotas and Polyzos, 2013a), where the edge weights may represent *kilometric distances* among pairs of nodes (capital cities) $v_i,v_i \in G(V)$ or commuting flows, consisting of the number of commuters that they are traversing an edge per direction, and the respective node weights may represent a set of socioeconomic attributes describing the capital cities of the prefectures of *Thessaly* and *Sterea Hellas*. The following analysis consists of the construction of an ordinal regression empirical model for the directed commuting network of figure 1, where the regression model is being applied. The results of the analysis are discussed and the spatial patterns are further illustrated.

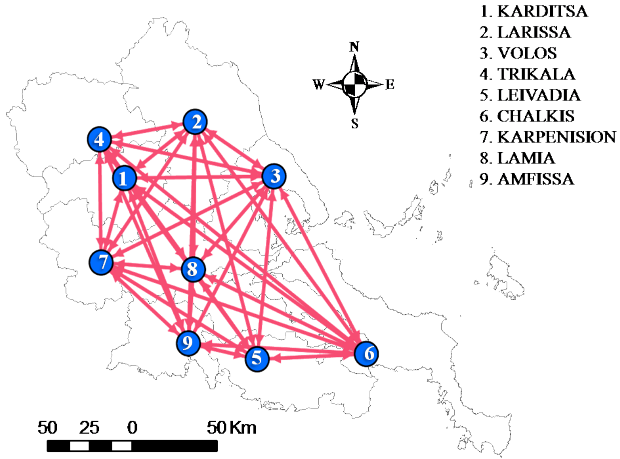


Fig. 1. The interregional commuting network of the regions of *Thessaly* and *Sterea Hellas* presented as a complete directed Graph $G(V,E)$

The data of the research refers, chronologically, to the year 2000 and, spatially, to the capital cities of the prefectures of Thessaly and Sterea Hellas, which are located in Central Greece. The study focuses on these commuting acts that originate from each capital city and arrive to any destination that exceeds the administrative limits of each municipality of origin (*outgoing commuting*). The available statistical data derive from the official census conducted by the *National Statistical Service* in 2001 (NSSG, 2004) and also from official data of the *Ministry of Energy and Climate Change* (former Ministry of Environment, Regional Planning and Public Works), as far as it concerns the kilometric distances of capital cities and settlements.

The quantitative approach of this study regards the construction and application of a statistical model of *ordinal regression*, which suggests the formation of a multivariate mathematic function $f : X \to Y$ between a dependent (response) variable (ordinal or hierarchical) $Y \in IR^n$ and a set of p independent (predictors) $X_i \in IR^n$, i=1,…,p. Ordinal regression models belong to the family of *Generalized Linear Models* (Nelder and Wedderburn, 1972) that, in accordance to common *General Linear Models*, inquire the estimation of a vector of coefficients $[b_i] = \overline{b} \in IR^n$ for the predictor variables of the model. The values of the estimated vector $\overline{b}$ express the amount of change in which the independent variables influence the dependent (McCullagh, 1980; McCullagh and Nelder, 1989).

The basic difference between Generalized and General linear models lies in the estimation technique, which is, for the first case, *maximum likelihood* estimation and *least square method* for the second, in correspondence. Also, another important difference between these families of models regards the variables' treatment. In ordinal regression, the continuous range of values of the respond variable is being discretized in a set of ordered categories. The limit values of each category's range are also estimations that do not depend on the respond variables prices, but on the probability assigned at each category. The categorical treatment of the dependent variable lends more stability in the model and it renders more importance to the ordering process of the categories, rather to the determination of their width. Consequently, the estimation algorithm of the model depends on the predictor variables and it is independent to the classification mechanism. This fact implies that the results of the model are expected to occur in parallel straight lines or planes. Furthermore, ordinal regression model applies a transformation to the values of the response variable, through a function, named *link function* that refers to the categories' cumulative probabilities (Norusis, 2004).

Ordinal regression model consists of three components, *location* and *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. Scale component constitutes a modification of the simple case model, so as to take under consideration the differences of variation between the independent variables. Lastly, 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 (1) (McCullagh, 1980; McCullagh and Nelder, 1989; Norusis, 2004),

$$link(\gamma_{ij}) = \frac{\theta_j - \sum_{k=1}^{p} b_k X_{ik}}{e^{\sum_{q=1}^{m} t_q z_{iq}}} \quad (1)$$

where the symbolism *link*() expresses 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 regards the regression's constant terms (thresholds) for each category, b_k refer to the coefficients of the predictor variables (location components, that are estimated by the maximum likelihood method), X_k are the k independent variables, $z_{i1}...z_{im}$ express the m defining variables for the scale component (that are being chosen between the predictor variables X) and $t_1...t_m$ express their coefficients.

2.2. Specialization of the model

The construction of an ordinal regression model suggests a decision making process that depends on the model's structure. Consequently, in accordance to the number of components of the model, this procedure depends of three decision pillars. The first choice regards the determination of the location component. In this paper, eight of the most representative theoretical defining factors of the commuting phenomenon are chosen as independent (predictor) variables and the *commuting distance* as dependent (response). The dependent variable is measured in *km* and was divided into four classes that are resulted from the analysis (table 3). The description of the response and the rest independent variables of the model is shown in table 1.

Table 1. Ordinal regression variables

Variable	Symbolism	Description	Measure	Data Source
Commuting distance	Y	Daily commuting distance (per capita) from resident to labor location	km	(NSSG 2004)
Number of commuters	X_1	Number of commuters per distance	Number of people	(NSSG 2004)
Size of the city of origin	X_2	Population of the city of origin	Number of citizens	(Epilogi, 2006)
Size of the city of destination	X_3	Population of the city of destination	Number of citizens	(NSSG 2004)
Population quality	X_4	Complex index that includes information for the educational level and for the locomotion acts of the population	Real number	(Petrakos and Polyzos, 2005)
Welfare of city of origin	X_5	Each prefecture's participation to GDP and per capita GDP	Percentage	(Petrakos and Polyzos, 2005)
Unemployment level of the city of origin	X_6	Number of unemployed of the city of origin	Number of people	(NSSG 2004)
Participation of the secondary sector at the GDP of the city of origin	X_7	Participation of the secondary sector to each prefecture's GDP	Non dimensional measure	(NSSG 2004)

Participation of the tertiary sector at the GDP of the city of origin	X_8	Participation of the tertiary sector to each prefecture's GDP	Non dimensional measure	(NSSG 2004)

The theoretical framework that describes commuting allows formulating some hypothesis, regarding the relation of the independent variable with the dependents. Initially, the relation between *the number of commuters* (X_1) and the respond variable (*commuting distance*) is expected to verify the inverse square analogy that is recorded in the theory. If not, the model will interpret an infinite demographic diffusion that seems to be opposed to the empiric observation. The relation between variable X_2 (*size of origin's city*) and commuting distance appears a twofold theoretical interpretation. According to the theories of expanding city, (Turner, 1985) these two variables are expected to present a negative relation, while, due to gravity theories (de Grange et al., 2011), they are expected to present positive. For the certain case of study, gravity theories seem to describe more properly this relation, because the urban sizes of the majority of Greek capital cities do not exceed the critical values, so as to present sprawl phenomena.

Next, variable X_3 (*size of the city of destination*) is expected to be related positively with the dependent variable, under the gravity perspective. The *quality of population* (X_4), if taking under consideration that it refers to the educational level of each capital city's residents, is expected to present a positive relation with the commuting distance. This hypothesis complies with the theoretical statement, that high level of education increases the labor competition (and the respective difficulty for vocational rehabilitation), fact that produces acts of seeking alternative work opportunities. Continuing, variable X_5 (welfare of the city of origin) is considered to be a commuting disincentive for the residents of the city of origin. The *unemployment level of the origin city* (X_6) is estimated to have a positive relation with the response variable, since high rates of unemployment create expelling population trends. As higher the *participation of the secondary sector at the GDP of the city of origin* (X_7) is, it produces high flows of workers inside the (origin) city borders and consequently it decreases the total commuting distance. Finally, *participation of the tertiary sector at the GDP of the city of origin* (X_8) produces flows of workers inside the urban tissue, fact which indicates that this variable may be uncorrelated with the commuting distance.

The next set of choices concerns the scale component. This part constitutes a modification of the basic ordinal model and its role is to count in any effects of the fluctuations that are caused by the differences among the independent variables. The embodiment of this component in the model is optional and aims to increase its overall fitting ability. As a result, the fundamental decision of the researcher is to determine whether it is necessary to use the scale component. The most common treatment here, is to exclude at the beginning the scale component and include it in the case that the bare model does not provide satisfactory results (Norusis, 2004). When the scale component's embodiment is considered essential, the next set of decisions regards the estimation the parameters of the model. In this study, the scale component did not included in the model, due to reasons of simplicity.

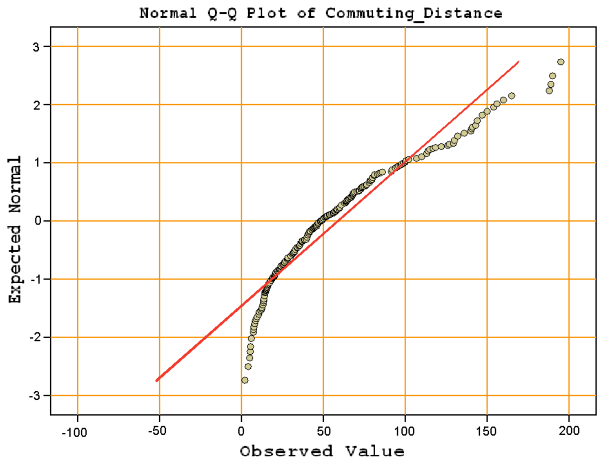
The last decision for the model's construction regards the type of the link function. The most suitable link function for the certain model turned to be the *complementary log-log* (Norusis 2005). This choice was guided from the distribution type of the independent variable, due to descriptive (*boxplots* and *histograms* construction) and statistical testing techniques. The tests that were applied are *Kolmogorov - Smirnov* (KS) (Massey, 1951) and *Shapiro - Wilk* (SW) (Shapiro and Wilk, 1965) and their results are shown at table 2. As it can be observed, both KS and SW statistics present an almost 0‰ statistical significance, which indicates that the empirical distribution of the commuting distance cannot be described by the normal curve.

Table 2. Normality testing statistics for the response variable

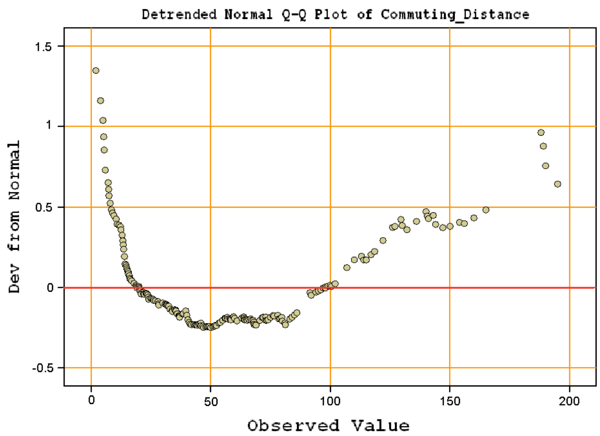
	Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
Urban sprawl	Statistic	d.f	sig.	Statistic	d.f	sig.
	0,105	320	0,000	0,917	320	0,000

[a] Under Lilliefors' correction of significance

The results of table 2 are verified by the Q-Q plots (Wilk and Gnanadesikan, 1968) of figure 2 and by the comparative diagrams of figure 3. Both normal (figure 2a) and detrended (figure 2b) Q-Q plots indicate that the empirical values present a significant divergence from the expected normal. This is graphically illustrated from the parabolic patterns (*j-shaped*) that the empirical values present at both plots of figure 2 (Norusis 2005).



(a)



(b)

Fig. 2. Percentile diagrams (Q-Q plots) of (a) normal probabilities and (b) deviation from normal probabilities (detrended normal Q-Q plot)

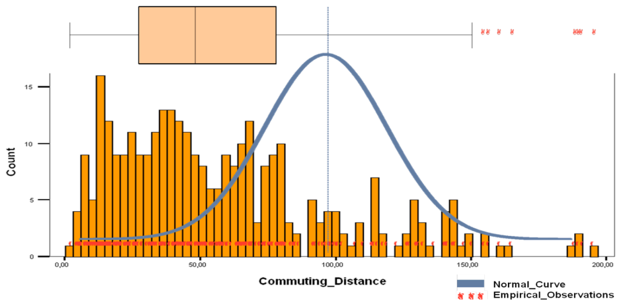


Fig. 3. (a) Box plot and (b) Histogram of the response variable's values

The determination of the response variable's distribution also led to the formation of the independent variable's discrete categories. As it can be observed from figure 3, the shape of the respond variable's distribution presents negative asymmetry, which indicates that distances of less than 100km are more common for Greek commutes. Also, the observation of distribution's local extremums provided some interesting results. First of all, the empirical mean of the distribution seems to be slightly less than 50km and to lie near the area of the 35km's local maximum. This observation indicates that commuters generally prefer to cover distances that range from 35-50km. Another local maximum is detected at the area of 20km that also suggests the most frequent value. This implies, that a significant number of commutes are conducted in neighboring zonal areas from the city of origin, which zones do not usually present considerable urban agglomerations. A next local maximum is formed at the area of 70km. This category refers to commuting destinations of important interregional urban cores. Finally, the outlier values that are observed at destinations above 75km, regard *extreme commuting* cases that are usually served by national road network facilities. The above observations imply to divide the range of the response variable's values into the four commuting categories of table 3.

Table 3. Descriptive statistics of the ordinal regression model

Variable	Category code	Category spacing	Degrees of freedom (N)	Category's percentage	Cumulative percentage
Commuting distance	[1]= Small	≤ 25,00	73	22,8%	22,8%
	[2]= Meddle	25 < Y ≤ 50	95	29,7%	52,5%
	[3]= Long	50 < Y ≤ 75	65	20,3%	72,8%
	[4]= Remote	> 75	87	27,2%	100%

The previous consideration of the response variable's empirical distribution leads to the choice of the *complementary log-log* as the most suitable link function for the model. This decision was conducted with the *abstractional method* (where the less proper functions are excluded from the choice) and was facilitated by the bar chart of figure 4, where it is indicated, that the ordinal categories present an increasing possibility trend. Due to this approach, the *Probit* function was rejected from the decision, because the empirical distribution was proven (table 2) that it does not fit in the normal curve. The *Cauchit* function was excluded also, since the empirical observations do not present lot of outliers (Norusis 2005).

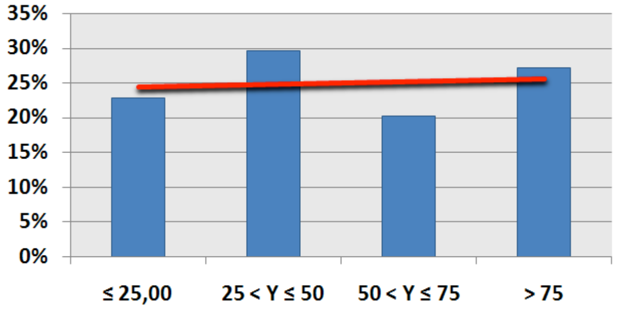


Fig. 4. Bar chart that indicates the observed percentages of the commutes for each category

3. Results and Discussion

After the determination of the components, the model is specified to the mathematical formula of relation (2), where $Y=y_j$ is the value of the dependent variable (commuting distance) for the category j. The rest terms of the relation were described previously.

$$\ln(-\ln(1-(P(Y=y_j))) = \theta_j - \sum_{k=1}^{7} \beta_k X_{ik} \qquad (2)$$

Before conducting the ordinal regression analysis, the fitness ability (goodness of fit) of the model is examined, by using the *double log likelihood* (-2LL) and the statistics of *Pearson* and *deviance* (McCullagh and Nelder, 1989; Norusis 2005). The calculations of these statistics are shown at table 4, where it can be derived that the certain ordinal regression model is preferred from the bare model.

Table 4. Goodness of fit statistics

Model	2 Log Likelihood		χ^2	d.f	sig.
Intercept only	880,343		---	---	---
Final	351,858		528,486	9	0,000

Pseudo R-Square			Goodness of fit statistics			
				χ^2	d.f	sig.
Cox and Snell	0,808					
Nagelkerke	0,863		Pearson	977,831	948	0,244
McFadden	0,600		Deviance	715,283	948	1,000

In the case of ordinal regression, where the response variable is categorical, three indicators describe the model's ability of determination, in contrary to the common use of R^2. These indicators that substitute the classical coefficient of determination (R^2) are called *pseudo-coefficients of determination* and are for ordinal regression the statistics of *Cox and Snell* (Cox and Snell, 1989), of *Nagelkerke* (Nagelkerke, 1991) and of *McFadden* (McFadden, 1974). The calculations of these pseudo-coefficients are also presented at table 4. The values of *Cox and Snell's* (0,808) and *Nagelkerke's* (0,863) statistics indicate an obvious good fitting ability for the model. The corresponding value of *McFadden* (0,600) can be considered acceptable, by the time this pseudo-coefficient suggests an entropy index of the model. Under the perspective that the pseudo-coefficients present lower values than the corresponding R^2 of the linear regression's case (Agresti, 1990; Norusis, 2004), the results of table 4 are satisfactory.

A last procedure for the evaluation of the model is the parallel lines test (table 5). This test opines for the universality of the model, because it helps to assess, whether the assumption that the parameters are the same for all categories is reasonable. Substantially, parallel lines test suggest a hypothesis testing (Berger, 1982; Tsiotas and Polyzos, 2013a), under the null hypothesis H_0: *the location parameters of the model are the same for all categories of the dependent variable* and the alternative H_1: *the general model stands that has different parameters per category*. Here, the statistical significance is calculated for the general model and, consequently, the null hypothesis is acceptable (Norusis, 2004) when *p value* (Doan, 2005) presents higher scores than 0,05 or 0,1 (McCullagh and Nelder, 1989). In the certain case of the ordinal commuting model the null hypothesis is accepted, since the statistical significance is 0,722 (table 5).

Table 5. Test of parallel lines

Model	-2 Log Likelihood	X^2	d.f	Sig.
Null Hypothesis	351,858			
General	192,880[(a)]	158,978[(b)]	18	0,722

(a) The log likelihood value cannot be further increased after maximum number of step-halving.
(b) The χ^2 statistic is computed based on the log likelihood value of the last iteration of the general model.

3.1. Estimation and interpretation of the model

The estimation results from the ordinal regression parameters and some statistics of the model (standard error, Wald's statistic, degrees of freedom, statistical significance, 95% confidence interval) are presented in table 6. The regression coefficient of variable X_1 is negative and its statistical significance is less than 0,001. The sign of this coefficient implies an inverse analogy between this variable with the dependent one, fact which indicates that a potential growth in commuting flows induces a corresponding decrease to the commuting distance. The regression coefficient of variable X_2 (size of the city of origin) presents an also negative sign and it has a statistical significant (2%) value. This relation describes that great cities of origin are less likely to contribute to large distance (>50km) commutes or, in other words, that these cities present a gravity performance, that tends to reduce "leak" phenomena of outgoing commuting. This outcome comes into an agreement with the theoretical background of gravity models (de Grange et al., 2011) and validates the initial hypothesis for the variable X_2.

Table 6. Ordinal regression model estimations

		Estimation	St. Error	Wald's stat.	df	sig.	95% conf.interval	
							Lower lim	Upper lim
THRESHOLD								
ω_1	Commuting distance[1]	14,005	5,557	6,353	1	,012	3,115	24,896
ω_2	Commuting distance[2]	15,424	5,559	7,699	1	,006	4,529	26,320
ω_3	Commuting distance[3]	16,145	5,564	8,419	1	,004	5,239	27,050
LOCATION								
	X_1	-0,012	0,002	57,052	1	0,000	-0,015	-0,009
	X_2	-4,93E-005	0,000	9,316	1	0,002	-8,09E-005	-1,76E-005
	X_3	1,16E-005	0,000	12,643	1	0,000	5,20E-006	1,80E-005
	X_4	0,138	0,062	4,951	1	0,026	0,016	0,260
	X_5	-0,250	0,104	5,835	1	0,016	-0,453	-0,047
	X_6	0,001	0,001	6,000	1	0,014	0,000	0,002
	X_7	-0,180	0,076	5,631	1	0,018	-0,231	-0,039
	X_8	0,105	0,037	8,093	1	0,004	0,033	0,177

Further, the regression coefficient of variable X_3 (size of destination city) has positive sign and a particular strong significance (<0,001). This result implies that the destination cities that are larger than the surrounding cities of origin are more likely to attract commutes of long distance and also refers to gravity theoretical background. Variable X_4 (population quality of the city of origin) presents a significant (p=0,026) regression coefficient, describing that as the educational level of a population increases then the willingness to commute if necessary also increase. This relation verifies the corresponding hypothesis of this paper, since more educated people are also more willing to travel in longer distances, in order to achieve higher salaries. Additionally, this outcome seems to agree with Van Ommeren et al.'s (2005) thesis, due to which commuting distance is positive correlated with the factors of productivity, of employee's payments and of profits of enterprises. Following, the regression coefficient of variable X_5 (welfare level of the city of origin) has positive and significant (p=0,016) value. This outcome interprets that welfare rises in the population of the city of origin, maintains labor potential within the city boundaries, reduces commuting leaks and decreases the commuting length. Commutes that originate from highly welfare cities seem that are constraint to short or middle distances (that rarely overcome distances of 50km). This seems reasonable under the remark that the welfare cities are more capable to satisfy people's demand for labor.

Continuing, the regression coefficient of variable X_6 (unemployment at the city of origin) presents a positive and significant (p=0,014) value. This result indicates the existence of unemployment in a city, produces expelling trends to the labor potential and consequently generates distant commuting flows. The last variables (X_7) and (X_8) regard the participation of the city's of origin secondary and tertiary productivity sectors to the GDP of the surrounding prefecture. Both regression coefficients have significant values (0,018 and 0,004 in correspondence), but their signs are opposite. The negative sign of variable's X_7 coefficient indicates that higher participation of the secondary sector of the city of origin to the regional GDP reduces the potential of long distance commutes. This statement seems reasonable, since the voluminous expansion of the secondary sector produces massive labor positions and, as a result, people occupy jobs within the suburban borders of the city of origin. On the other hand, the positive regression coefficient of variable X_8 implies that higher participation of the secondary sector of the city of origin to the regional GDP increases the potential of long distance commutes. This statement is due to location reasons of the tertiary sector's activities that occupy the central urban web and expel the rest economic sectors activities installation to out center zones.

3.2. Spatial Patterns of Commuting

Table 7 presents the ordinal regression commuting analysis results for the Greek regions of *Thessaly* and *Sterea Hellas*. As it can be observed, a double volume of outgoing commuting is conducted in the region of *Thessaly* in comparison with region of *Sterea Hellas*. In intraregional level the most significant commuting flows are noted at the city of *Larissa*, secondary at *Volos* and following at *Trikala* and *Karditsa,* in descending order. Respectively, in the region of *Sterea Hellas* the highest commuting flows are observed at the city of *Chalkis*, secondly at *Leivadia* next at *Lamia* and *Amfissa* and finally at *Karpenision*. Figure 5 illustrates the above observations (in bar charts) for outside of municipality borders commuting destinations and figure 6 for the respective inside the municipality.

Table 7. Commuters for regions of Thessaly and Sterea Hellas.

Administrative Unit	# commuters out of muncipality	% population	# commuters within muncipality	% population	$\sum_{j=1}^{k} d_{ij}$	$\frac{\sum_{j=1}^{k} d_{ij}}{k}$	d_{max}
REGION OF THESSALY							
KARDITSA	1035	7%	13046	91%	27461	26,5	189
LARISSA	3747	8%	44287	89%	92144	24,6	144
VOLOS	3577	12%	25581	85%	73664	20,6	190
TRIKALA	1813	9%	18420	88%	44415	24,5	110
TOTAL	10.172	9%	101.334	88,3%	237.684	24,05	158,25
REGION OF STEREA HELLAS							
LEIVADIA	917	11%	7175	86%	42014	45,8	144
CHALKIS	4014	19%	15913	77%	97494	24,3	129,5
KARPENISION	46	2%	2784	94%	2048	44,5	150
LAMIA	1084	5%	20423	92%	45797	42,2	165
AMFISSA	144	5%	2581	92%	4536	31,5	147
TOTAL	6.205	8,4%	48.876	88,2%	191.889	37,66	147,1

% = percentage, # = number, count, d_{max} = max distance, $\sum_{j=1}^{k} d_{ij}$ = total daily one-way distance, $\frac{\sum_{j=1}^{k} d_{ij}}{k}$ = mean daily one-way distance

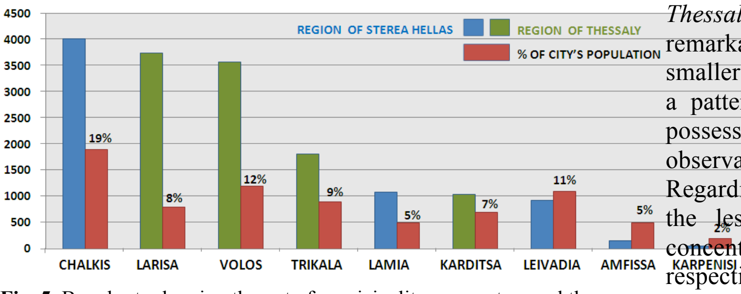


Fig. 5. Bar charts showing the out of municipality commuters and the corresponding percentages (city of origin)

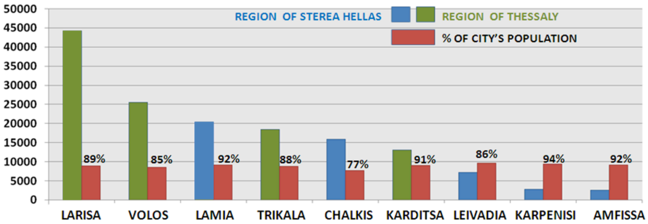


Fig. 6. Bar charts showing the within municipality commuters and the corresponding percentages (city of origin)

Figures 5 and 6 provide information regarding the spatial patterns of commuting for the mentioned regions. If taking under consideration the absolute population values of figure 5 (out of municipality borders), the result is, that the most populated cities of origin produce in both regions the strongest outgoing commuting flows. This observation seems to be in a contrary to the one that is extrapolated from the respective percentage bar chart calculations. In the second case, *Larissa* city in the region of *Thessaly* (presenting 8% commuting) shifts its position in the ranking from the 1st (in terms of absolute values) to the 3rd (in terms of percentage values) place following the cities of *Volos* and *Trikala*. Consequently, the percentage ranking in the case of *Larissa* is more probable to illustrate the city's gravity performance, due to which *Larissa* seems to be more capable to conserve its labor population inside its municipality borders rather than to produce outgoing commutes.

In the region of *Sterea Hellas*, the city of *Chalkis* occupies the 1st position in both ways of ranking. The second city, in terms of percentage values, is *Leivadia*. This ordering seems reasonable, due to the closeness of these cities to the city of Athens and to the wider industrial zone between the prefectures of *Attiki* and *Voiotia*. Secondly, the city of *Karpenision* presents insignificant outgoing commuting, probably due to reasons of its geomorphology that impedes easy access of this city to the national highway road network. Finally, through a regional perspective, the two above regions appear an almost equivalent overall commuting performance, since the total percentage of labor that commutes is 9% for *Thessaly* and 8,4% for *Sterea Hellas*.

On the other hand, the interpretation of figure 6 can provide information regarding the attractive (gravity) behavior of these capital cities that induces commutes inside the municipality borders. Due to further interpretation, figure 6 illustrates the volume of *labor cohesion* that each city of the above regions presents. The observation of figure 6 validates the attractive gravity performance of the city of *Larissa* (region of *Thessaly*) and the weak concentration attitude of *Chalkis* (region of *Sterea Hellas*), obviously for the reasons mentioned above. In the case of the region of *Thessaly* the low percentage cohesion of the city of *Volos* is remarkable in comparison with the rest cities of *Thessaly* of smaller population size. The case of *Thessaly* also illustrates a pattern of strong cohesion trends for these cities, that possess a significant rural based economy, but this observation suggests an individual topic of further research. Regarding the case of region of *Sterea Hellas* it seems that the less accessible capital cities present greater labor concentration performance in comparison with the respective that are placed nearby the national highway road network (such as *Chalkis* and *Leivadia*).

3.3. Commuting Density and Load of Traffic

As it results from the mean commuting distances $((\sum_{j=1}^{k} d_{ij})/k)$ (table 7), the greatest size of the outgoing commutes seems to have destinations into settlements or towns that are located inside the spatial zone of influence of each capital city. The commuting flows in the region of Thessaly do not arise to be significant, under the observation that the mean commuting distances of table 7 are smaller than the corresponding intercity distances, between each pair of capital cities. On the other hand, the respective commuting flows in *Sterea Hellas* region are greater than in *Thessaly*'s, which is verified by the mean commuting difference $\bar{d}_{St.Hellas} - \bar{d}_{Thessaly}$ =37,66-24,05=13,61km. A significant gravity parameter that probably shapes this difference is the attractive role of (the neighbor city of) *Athens* to the capital cities of *Sterea Hellas*. Nevertheless, it cannot be observed from table 7 any existence of considerable interregional commuting flows between these two regions. Specifically, table 7 shows that the larger part of commuting (almost 66%) is conducted to destinations within a radius of 25km from the capital city's center. At the next commuting destination ring (25-50km), the density percentage reaches 20%, at the third ring (50-75km) it reaches 10% and at the last commuting area (>75km) it is almost 4%. This spatial commuting density distribution that arises from the empirical data of this paper seems to verify the binomial rule $y = \alpha x^2 + \beta x + \gamma$.

As far as it concerns the amount of the daily produced vehicle-kilometers ($\sum_{j=1}^{k} d_{ij}$) of table 7, which can suggest an indicator of the road network's *load traffic capacity*, some considerable differences can be distinguished for the above commuting density zones. From the total of 860.000km that are daily covered in these two regions, an amount of 32% (277.000km) is distributed at the zone of <25km, of 26% (232.000km) at the ring of 25-50km, 24% (207.000km) at the ring of 50-75km and the last 16% (144.000km) at the last supplementary area. This relation between the daily commuting covered distance and the produced vehicle-kilometers seems that in the case of the traffic load capacity it can be described from a logarithmic linear rule $y = \alpha + \beta \ln x$. Figure 7 illustrates these two distributions in a comparative diagram.

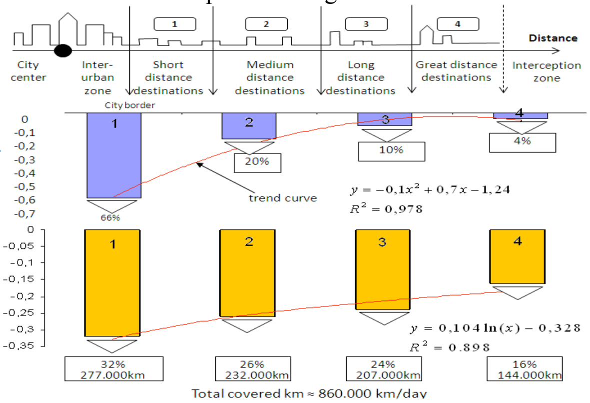


Fig. 7. Daily commuting density and traffic load distributions with their estimation curves for the regions of *Thessaly* and *Sterea Hellas*.

3.4. Regional Economics' Parameters

The commuting phenomenon suggests a research field of great interest for the regional Science and has a multidimensional framework that is composed by many components, such as demographic, geographic, economic and political (Polyzos, 2011). The demographic component seems to be of great significance for the patterns of daily commuting (destination, length, volume and density of commuting). In the present case, the demographic components that were taken under consideration in the ordinal regression model, are the predictor variables X_1 (number of commuters), X_2 (size of the city of origin), X_3 (size of the city of destination), X_4 (population quality) and, under conditions, variable X_6 (unemployment level of the city of origin). As it results, an amount of over 50% of this ordinal regression model is structured on a demographic foundation. This observation reveals that commuting initially suggests a social phenomenon of regional scaling that is further determined of economic, geographic and political factors.

The foregoing ordinal regression analysis indicated that the densest urban agglomerations appear more attractive as commuting destinations, probably due to their greater economic size and their presented increased opportunities of employment. Commuters, under the motivation to seek better opportunities of employment and work quality, appear more willing to cover longer distances and this willingness is transformed into a typology of interactive commuting patterns (Gordon et al., 1991; Muniz and Galindo, 2005), some of which were also elected in this paper. The properties of Regional economy also wield to the spatial characteristics of the commuting phenomenon, since the economic component interacts with the social structures and their consequent anthropogeography (Lee and McDonald 2003).

The sectorial-based structure of economy suggests a significant criterion for the decision making of the commuting distance that commuters are willing to cover. Obviously, the presence of secondary sector produces a mass number of employment positions within the urban web and, as a result, it shrinks the size of commuting. Furthermore, the commuting distance seems also to be constrained by the welfare level of the city of origin, under the concession of the employees' rationalism. Welfare cities of origin offer higher standards of living and consequent higher employment opportunities that result to labor potential concentration and to further commuting distance reduction. On the other hand, the growth of the tertiary sector seems to form the conditions for longer commutes, by the time that the centralized location of the tertiary sector's services produces expelling trends to the rest economic activities.

4. Conclusions

The daily commuting suggests a multidimensional phenomenon in Regional Science that is driven by social, economic, geographic and political forces. This paper has conducted a literature approach of the phenomenon and also an empirical ordinal regression case study for the Greek regions of *Thessaly* and *Sterea Hellas*. The foregoing analysis rendered insufficient to produce a holistic spatial typology of the phenomenon, but it elected an amount of short scale patterns that come to an agreement with the theoretical framework for the Greek case. For example, although the capital cities of *Volos* in the region of *Thessaly* and of *Leivadia* in *Sterea Hellas* present different commuting mean distances (20,6km and 45,8km respectively) as also the cities of *Karpenision* and of *Chalkis* in *Sterea Hellas* present different amounts of commuting population (2% and 19% in correspondence) or of vehicle-kilometers (2.048km and 97494km respectively) the density and traffic load distributions of all above cases seem to follow a binomial rule. The quantitative analysis indicated that each capital city presents an individual micro-world profile that depends on geographic (spatial variation), demographic (size of urban units), economic (economic structures, volume of employment) and related factors. Such urban micro-worlds interact and generate a spatial commuting system, which was described in this paper with the ordinal regression analysis for the Greek regions of *Thessaly* and *Sterea Hellas*.

The conclusion making of this ordinal regression analysis produced interesting outcomes, which should suggest a consultative material for the strategic planning of the policies that aim to control the commuting driving forces, in order to develop a better transportation interregional and hinterland framework. For example, the transportation infrastructure policies that refer to road network maintenance should take under consideration the commuting distance and the commuting traffic load distributions. Additionally, these policies that target to upgrade the standards of living of the population should also take under consideration the effort that is daily being spent on commutes. Furthermore, some modern developing theories, such as *sustainable cities*, seem to be correlated with the commuting phenomenon. Finally, some environmental issues that arisen by the frequent use of private use vehicle, should point to the control of the commuting phenomenon.

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