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THE EGNATIA MOTORWAY AND THE CHANGES IN INTERREGIONAL TRADE IN GREECE: AN EX ANTE ASSESSMENT

Abstract: The Egnatia Motorway, located in the northern part of Greece, constitutes one of the most important, as well as ambitious, projects of the Trans-European Transport Networks programme (TETN) funded by the European Commission. It is expected to greatly influence the spatial economic relationships of several regions across the country. The motorway crosses all administrative regions of Northern Greece, and the expectations currently sustained by the public as regards its contribution to regional development are exceptionally great. As numerous empirical studies have already shown, the most important changes in regional economy induced by interregional transportation infrastructure are associated with trade flows between different regions. This paper analyses the major determinants of interregional trade in Greece and estimates the changes in interregional trade flows which the construction of the Egnatia Motorway is capable of generating.
Key words: interregional trade, transportation, regional economic development, productivity.

1. INTRODUCTION

The contribution of interregional transportation infrastructure to regional economic development and to mitigating spatial economic asymmetry is widely recognised. A lot of researchers sustain the view that the construction of new transportation infrastructure is a ‘tool’ of great importance, both in boosting economic development and in reducing interregional economic inequalities (Rietveld, 1994; Rephann and Isserman, 1994; Vickerman, 1996). The critical

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role of infrastructure as well as the importance of the fixed social capital generated during the infrastructure construction process has been firmly stressed by theorists of economic development. Additionally, in a lot of theoretical models, infrastructures are considered as ‘propeller’ factors of development, due to the fact that they are believed to create the necessary conditions for the economy to operate effectively as well as to ‘take off’.

The construction of interregional transportation infrastructures contributes to the decrease in ‘friction resistance’ between the regions and to the increase in interregional trade exchanges. Trade exchanges between regions may constitute the most significant economic activities, which are closely related to the level of development achieved by regions, and are also decisively influenced by distances and transportation costs, as relevant research on the scientific field implies (Liew and Liew, 1984; Sasaki *et al*., 1987; Polyzos and Petrakos, 2000; Polyzos, 2001). According to the seminal theory of interregional trade developed by Heckscher–Ohlin, a reduction in ‘friction resistance’, in the long-term, results in boosting local accumulation processes and sectoral differentiation while at the same time prices of the production factors, capital and labour, tend to equalise leading to reduction of regional inequalities.

Fig. 1. The Egnatia Motorway

From a national as well from a European point of view, the Egnatia Motorway is one of the larger interregional transportation infrastructures currently under construction (see figure 1). It may be the largest transportation infrastructure constructed in the last decade, with great national and international signify-cance. It is a part of the Trans-European Transport Networks (TENT) programme of the European Union, an enormous infrastructure investment programme targeted at reducing the inequalities between European regions and achieving a more balanced regional economic development (Panebianco and Schürmann, 2002). The arrangement of the motorway in a position parallel to the northern borders of the country provides the possibility of utilising it either independently or in conjunction with the traverse transportation network and it is expected to influence the interregional economic relations of the country.

The reduction in interregional distances brought about by the motorway is expected to cause changes in the degree or the intensity of the spatial interdependence and interaction between economic activities in Greece. It is also expected to facilitate spatial unification processes, to increase interregional commercial competition, and to give rise to new dynamics regarding interregional economic inequalities. Taking into account the fact that there currently exist important differences in the level of economic growth amongst Greek prefectures, a legitimate question emerges about the 'direction' of the future economic changes. That is to say, what will be the effect of the motorway on the process of regional development and what will be its contribution to a polarising or decentralising process. This is a question that usually preoccupies most of the planners in the process of evaluating the economic impacts of interregional transportation infrastructures (Fayman *et al*., 1995; Vickerman, 1996; Sdrolias *et al*., 2005).

This article investigates the size and the direction of interregional commercial changes that the Egnatia Motorway is expected to bring about, by means of an ex ante quantitative analysis. In particular, a number of equations are proposed and calculated regarding the direct and indirect changes in interregional trade that are expected to happen both in the prefectures that the motorway crosses and in the rest of the mainland prefectures of the country. By using real statistical data, the parameters of the proposed equations are estimated and the influence of the interregional time-distance changes on the size of interregional trade for the mainland prefectures of the country is assessed. Finally, an evaluation of the final results is made and general conclusions are formulated.

2. DISTANCES AND INTERREGIONAL TRADE FLOWS

In its recent form, interregional trade theory incorporates transportation cost into its calculations and estimates a region's comparative advantage as a function of its production advantage and the transportation advantage (Dugonjic, 1989; Johansson and Westin, 1994). The comparative advantages of two regions r and s in relation to a third region can be depicted by the relationship P_s< or >P_r+(T_r – T_s), where *P* is the production cost and *T* is the transportation cost of the regions in relation to the third region. The possible change in the interregional transportation cost between the regions, deriving from the construction of a new transportation infrastructure or from upgrading the existing transportation network, is expected to differentiate the total comparative advantage assigned to each region and also to influence interregional trade. Moreover, the comparative advantage can change after the production cost for each category of products has been changed.

The necessity for evaluating the impacts on economic development caused by state policies (e.g. construction of transportation infrastructure, reduction in duties and policies in favour of free-trading, alterations in the comparative advantage of certain areas via improvements in productivity etc.), has led to the emergence of a plethora of methodologies and models for estimating and forecasting trade flows. These methodologies usually rely upon simulation techniques.

A common procedure amongst methodologies for estimating and forecasting trade flows is the incorporation into a model of determining factors, the most important of which are the production cost and the interregional transportation cost, subject to different types of products (Amano and Fujita, 1970; Wilson, 1971; Brocker, 1980; Erlander, 1982; Sasaki *et al*., 1987; ACT Consultants *et al*., 1992). This presupposes perfect knowledge of the production cost and of the final values involved in each sector of production on a regional level. However, it is unlikely to meet this requirement at least in countries that do not possess the necessary statistical organisation and experience. Thus, when employing a particular methodology, the accuracy of the results depends highly on the volume of necessary observations for calibrating the methodology.

When trade flows from region *s* to region *r* are expressed as percentages of total imports of region *r*, then it is $\sum_{s=1}^{n} t^{sr} = 1$, while when trade flows are expressed as absolute quantities, then it is $\sum_{s=1}^{n} t^{sr} = D^r$, where D^r is the total demand or the total imports including imports of region *r*.

Most of the models used are spatial interaction models and, on the bases of equations they employ, they can be classified into two broad categories (Peschel, 1981):

1. Gravity models.
2. Optimisation and linear programming models. These models utilise entropy optimising principles (entropy models) or principles for optimising individual consumers' utility in conjunction (in some cases) with the transportation problem issue. These models usually tend to be models of gravitational nature.

Gravity models aim at interpreting trade flows on the basis of Newton's Law of Universal Gravitation (Amano and Fujita, 1970; Treyz, 1980; ACT Consultants *et al.*, 1992). After constructing the proposed model the calibration stage follows and, subsequently, the stage of estimating the values of the model parameters using empirical data. Assuming that the commercial relations among regions are temporarily stable – in other words, the degree of influence of the factors that determine the relations does not change – it is possible to forecast the potential changes due to a change in the magnitude of one or more determining factors, using the estimated values.

The optimisation models often lead to similar equations with the gravity models through the process of maximising entropy or consumer' utility subject to certain constraints (Wilson, 1971; Erlander, 1978; Bröcker, 1980; Erlander, 1982; Hallefjord and Jornsten, 1986; Sasaki *et al.*, 1987). Usually, independently of the form that the models take, they rely on the basic assumption of perfect market competition. They also presume consumers' perfect knowledge of product prices, independently of the distance between the places of production and the places of consumption. A final assumption is that commercial exchange or the resultant trade flows are not influenced by other factors. The neoclassical economic theory forms the base of optimisation models. According to this theory, the individual consumer's behaviour aims at maximising their utility deriving from goods and services that he or she consumes.

The gravity and gravitation-type models have been widely used in estimating not only trade flows but also numerous other spatial flows. They have been applied in economic studies, transportation planning exercises and in the fields of geography, regional development and sociology (Wilson, 1971). These models are mostly popular among regional researches due to the fact that the alternative models of maximisation suffer from the assumption of perfect competition (Peschel, 1981).

In the context of interregional trade, a general representation of the models that estimate trade flows T_i^{sr} of economic sector i from s (origin) to region r (destination), can take the mathematical form $T_i^{sr} = f(X_i^s, Y_i^{sr}, P_i^s, C^{sr})$ $(s \neq r = 1, ..., m)$, where X^s is a factor which produces trade flows, Y^r is a factor which 'attracts' the trade flows, P_i^s is a factor which represents the production cost and C^{sr} is the transportation cost, while $\partial f/\partial X^s > 0$, $\partial f/\partial Y^r > 0$, $\partial f/\partial C^{sr} < 0$ is valid. When the variable P_i^s represents the production cost then: $\partial f/\partial P_i^s < 0$, while when the variable represents the productivity then $\partial f/\partial P_i^s > 0$.

3. PROPOSED MODEL FOR ESTIMATING TRADE FLOWS

As was mentioned before, the construction of a valid model for calculating trade flows requires a minimal volume of statistical data for model and parameters calibration. Due to the fact that the availability of specific statistical data in

Greece is limited, a spatial interaction model has been constructed. In the model the variables per sector for regions *s* and *r* are: (a) time – distances d^{sr} between region *s* and region *r*, (b) the employment E^s and (c) the productivity p^s. For these variables sufficient statistical information exists.

A common practice among the methodologies mentioned before is the incorporation of production cost, in addition to transportation cost, for each group of products on a regional scale. It is believed that production cost is a measure of the production advantage as well as of the potential for commercial exchanges sustained by a region. This however presupposes precise knowledge of the production cost and the final values for each productive sector per region, something which is extremely difficult for countries without the necessary statistical experience and organisation. In the proposed model we incorporate 'productivity' per productive sector and prefecture, assuming that productivity 'portrays' better the production capability, with regard to the final cost of production and thus to the comparative advantage of each prefecture. Differences in productivity of necessary labour for producing the same product imply differences in the cost of production. A number of empirical studies about international trade suggest that there is a linear correlation in logarithmic form between the rate of labour productivity and the rate of exports of trading countries (Krugman and Obstfeld, 2002).

The exclusive use of 'productivity' as the determinant of regional advantage level presupposes the acceptance of the basic assumption that the configuration of the final cost is mainly determined by the productivity and the efficiency of each region's production system. This assumption may be valid, as long as wages (assigned to different occupations) are the same for all regions and they also do not change considerably due to spatial differentiation in average productivity or in competitiveness. In the case of Greek regions, two facts guarantee that the above condition is met: (a) the existence of a national labour collective agreement by which minimum wage levels are determined (thus, as far as the configuration of the final cost of production is concerned, the possibility of important differences in wages between regions is minimised) and, (b) the elasticity in the mobility of labour between the regions. Hence, we consider that the cost of production is linearly connected with the productivity of each region.

The proposed model is based on the following *assumptions:*

1. The trade flows, in almost all models, are reversely proportional to interregional time-distances d_{sr}. Distance decisively influences transportation cost, impedes spatial diffusion of information about market conditions and thus introduces uncertainty to the interregional transactions and to the trade affairs (Peschel, 1981; Argyris, 1992). As is supported by Gordon (1978), the effect of distance on products possessing different value is different and that is due to the

difference between perceptible and real transportation cost or otherwise the mental map of individuals changes geometrically in relation to the real geographic distance.

2. Trade flows are proportional to the productive capability of each region (associated with the volume of goods and services that a region can produce). The difficulties in estimating the existing capital per region, the degree of capital utilisation as well the quality and general characteristics of capital drive us away from utilising capital metrics as determinant factors of the productive capability of each region. This leads us to the solution of connecting the regional productive capability with the total employment E^s by sector for each region.

3. Finally, as was mentioned before, the obvious difficulties in calculating the cost of production of each product in each particular region as well as the requirement of incorporating competitiveness and productive capability in the model, lead us to the solution of connecting the trade flows with the average productivity p_i^s of each sector. We suppose that an increase in productivity of each particular sector ensures lower cost of production or that an increase in productivity improves the relevant placement of the particular region in the economic competition ranking.

Thus, the trade flows from region (prefecture) *s* to region (prefecture) *r* – represented as percentages of the total imports of region *r* – will derive from the following mathematical formula:

$$t_i^{sr} = k_i \, (E_i^s)^{\alpha} \, (p_i^s)^{b} \exp(-cd_{sr}). \tag{1}$$

In order to account for the relation $\sum_{s=1}^{m} t_i^{sr} = 1$, the above equation can be written as:

$$t_i^{sr} = \frac{(E_i^s)^a (p_i^s)^b \exp(-cd_{sr})}{\sum_{s=1}^{m} (E_i^s)^a (p_i^s)^b \exp(-cd_{sr})}. \tag{2}$$

This equation contains calculations for parameters *a*, *b* and *c*, while the existing statistical data for the variables E_i^s, p_i^s, d_{sr} are satisfactory got the prefecture level. The main advantage of the proposed model derives from the incorporation of productivity as one from of the determinant factors of trade. As will be shortly presented in detail, the construction of transportation infrastructures in addition to distance or to transportation cost influences the productivity of enterprises, because it encourages the spatial diffusion of technology and the adoption of more efficient methods of production.

4. ESTIMATION OF MODEL

For the calculation of model parameters real trade flows are used between the prefectures of the country, as these were measured in the last *National Research of Origin – Destination* of the Ministry of Public Works (1997). Also, statistical data from NSSG (2001, 2002) have been used for employment, for calculating productivity and for variable d_{sr}. For variable d_{sr} the centroid time-distances between the 39 mainland prefectures of the country elements of another study have been used (MNE, 1993). Equation (1) is estimated by using the ordinary least squares (OLS) method, with data only for the 39 mainland prefectures of Greece.

Insular prefectures were excluded from the estimations because their general characteristics relevant to trade and transportation infrastructures are different from those of the mainland areas. The characteristics of the transportation connections are different, since the connections of the mainland prefectures are road connections, while for the insular prefectures, the marine route/way and the air links/connections have decisive importance. The connections of insular prefectures involve higher costs, are characterised by higher uncertainty in comparison to the connections of the mainland prefectures, i.e. they depend on the prevailing meteorological conditions – and are made almost exclusively by public means of transportation.

Multiple regression analysis is used for calculating the parameters of equation (1), which constitutes an unconstrained gravity model. Employing logarithms on the two parts of the equation we obtain:

$$\ln t_i^{sr} = \ln k_i + \alpha \ln E_i^s + b \ln p_i^s - c d^{sr}. \quad (3)$$

The available statistical data about merchandising transports and exchanges between prefectures include the following categories of products: (a) agricultural products; (b) industrial and chemical products; (c) minerals, combustibles and lubricants; (d) construction materials (MPW, 1997). For calculating minimum productivity per sector and prefecture, both the employment for the year 2001, as it was recorded in the National Inventory and the GDP for the year 1997 were used (NSSG, 1998, 2001, 2002).

For calculating productivity in the category of construction materials, due to lack of GDP data (these data are aggregated into the data concerning the whole sector of manufacturing), we use the productivity of the manufacturing sector. For the category of minerals, combustibles and lubricants, because they fall into two different sectors according to the classification of NSSG, we use the productivity that corresponds to the minerals sector. We estimate the parameters of the variables of equation (3) by using the method of ordinary least squares (OLS). The results are presented in table 1.

Table 1. Estimation of parameters of the factors *E*, *p* and *d* and the formation of interregional trade flows by OLS

Dependent variable: $\ln t_i^{sr}$

Independent variables	Estimators of parameters	Values of *t* distribution	Significance of *t*	
Agricultural products				
Constant	–0.1610	–0.321	0.748	$R^2 = 0.55$ $\text{adj}R^2 = 0.55$
E	0.3560	24.220	0.000	
p	0.6780	6.480	0.000	
d	–0.0058	–24.380	0.000	
Industrial and chemical products				
Constant	–0.0270	–0.658	0.510	$R^2 = 0.58$ $\text{adj}R^2 = 0.58$
E	0.4130	29.850	0.000	
p	0.4050	5.066	0.000	
d	–0.0061	–24.700	0.000	
Minerals, combustibles and lubricants				
Constant	0.074	2.48	0.013	$R^2 = 0.71$ $\text{adj}R^2 = 0.70$
E	0.770	48.34	0.000	
p	0.160	4.42	0.000	
d	–0.007	–25.57	0.000	
Construction materials				
Constant	0.0189	0.589	0.555	$R^2 = 0.71$ $\text{adj}R^2 = 0.71$
E	0.637	57.200	0.000	
p	0.426	8.150	0.000	
d	–0.008	–33.090	0.000	

One of the basic econometric problems that is caused by the violation of assumptions assigned to explanatory variables in the linear models – this problem will be checked on for the proposed model – is multicollinearity. Without presenting every single result, we report the cases where high correlation coefficient values between the model's independent variables are found. Thus, there is high correlation between 'employment' and 'productivity' (0.79) in the case of agricultural products, between 'employment' and 'productivity' (0.76) in the industrial and chemical products, between 'employment' and 'distance' (0.73) in minerals, combustibles and lubricants and between 'employment' and 'distance' (0.72) in transporting construction materials. Due to the fact that in statistical samples some degree of multicollinearity always exists, explicit criteria for characterisation of this multicollinearity as harmful do not exist. The model's ability for forecasting is not influenced if the same relation of linear dependence that exists between the explanatory variables continues to exist also in the period of forecast.

We can say that the existing correlation is justified as well as expected, especially between employment and productivity, as long as high employment is linked to agglomeration economies, which in turn, constitute a defining factor of productivity. By closely observing the results in table 1, we realise that for employment exponent *a* takes values from 0.35 to 0.77, for productivity exponent *b* takes values from 0.16 to 0.67 and finally, exponent *c* for ‘distance’ varies between 0.0058 and 0.008. Thus, ‘employment’ seems to have a higher influence on the trade of minerals, combustibles and lubricants, while its importance is limited in the case of agricultural products.

As regards distance we observe a relatively smooth development of its influence with higher values of the exponent, and hence lower influence, in the transportation of construction materials and with increasing importance in the case of minerals, combustibles and lubricants trade, industrial and chemical products as well as agricultural products. This differentiation of the exponent of distance can be due to two reasons: firstly, it may be relevant to the weight of products of each category and secondly to the values of these products. Merchandises of high value are transported over longer distances, while in the case of commodities of large weight distance is a significant factor, something that has also been suggested by a number of empirical studies (Black, 1972; Gordon, 1978).

5. INTERREGIONAL DISTANCES AND PRODUCTIVITY

The construction of the Egnatia Motorway will alter the interregional trade flows because of the influence on the two determinant factors namely time-distance d^{sr} and productivity p^s. The change in time-distance is obvious, while the change in productivity will be commented upon and justified shortly. The interregional comparison of productivity (added value per employee), on the level of considering the regional economy as a whole, as well as on the level of each particular regional productive sector, leads to the conclusion that there are important differences in productivity values for the geographical regions of the country (Skountzos, 1992).

For calculating the relation between ‘distance’ and regional productivity the following general not-homogenous production function is used:

$$Q = \alpha_0 \prod_{i=1}^{n} X_i^{ai} \exp[\sum_{j=1}^{m} b_j Y_j], \qquad (4)$$

where X_i and Y_j are factors of production or factors that determine the level of produced commodities and α_0, α_i, and b_j are coefficients which show the elasticity of each factor.

The differences, which are observed in the values of sectoral productivity, are due both to the different structure of regional economies and to a number of other factors, the most important of which are presented below:

(a) The used capital per employee, as long as the efficiency of the production system is proportional to both quantity and quality of utilised capital per employee.

(b) The size of enterprises, because higher distribution of labour, better organisation and the degree of utilisation of inanimate and living capital are directly related to the level of production and to the size of each particular enterprise.

(c) Agglomeration economies or localisation economies. This refers to the concentration of a lot of enterprises of the same or similar sectors in a particular location, a trend which encourages production specialisation and improvement in the average productivity of the system. Even, localisation economies are a result of many enterprises – not necessarily belonging to the same sector – choosing to locate in the same geographical area.

(d) The social capital. The level of education, skills and training of a region influences the average output and hence the productivity of the system.

In addition to the factors mentioned before, the configuration of the level of productivity in each prefecture is influenced by the quality of technology used. Technology constitutes one of the most important factors of economic growth, as long as, given the quantity of capital and labour, an increase in productivity of our economic system by technological means is possible. The distance of regions and enterprises from technology and innovation production centres influences the average productivity, because the spatial diffusion of technology, information and technological knowledge is impended (Richardson, 1972, 1978; Brocker, 1980; Argyris, 1991).

In the present research we will estimate the effect of distance of Greek prefectures from the centres of technology and innovations production on the configuration of the average productivity in the primary and secondary regional sectors. For these sectors there exists statistical information on the prefectural level. As regards the tertiary sector, despite our earlier estimate that there is some effect of distance on the regional level, the calculation of this effect is not feasible with existing statistical data, while many of the products of this sector are considered as non tradeable.

The specialisation of equation (4), for the above mentioned factors, yields, for the primary and secondary sectors respectively, the following equations:

$$Q = \alpha_0\ X_1^{a1}\ X_2^{a2}\ X_3^{a3}\exp[b_1Y_1 + b_2Y_2 - b_3Y_3 + b_4Y_4] \quad (5)$$

$$Q = \alpha_0\ X_1^{a1}\ X_2^{a2}\exp[b_1Y_1 + b_2Y_2 - b_3Y_3], \quad (6)$$

where: Q – output of each sector of production; X_1 – used capital for producing the output Q in the secondary sector and the cultivated agricultural areas in the primary sector; X_2 – total employment used for the production of output Q; X_3 – the number of used instruments (the amount of tractors used); Y_1 – indicator of the employers' level of training and education; Y_2 – indicator of scale economies; Y_3 – time-distance of the prefectures from technological centres; Y_4 – the quantity of irrigated areas in primary sector.

Dividing the components of equations (5) and (6) by X_2, we obtain the next equations:

$$\frac{Q}{X_2} = \mathrm{a}_0\ (\frac{X_1}{X_2})^{a1}\ X_2^{a1+a2-1}\ X_3^{a3}\exp[b_1Y_1 + b_2Y_2 - b_3Y_3 + b_4Y_4]; \quad (7)$$

$$\frac{Q}{X_2} = \alpha_0\ (\frac{X_1}{X_2})^{a1}\ X_2^{a1+a2-1}\exp[b_1Y_1 + b_2Y_2 - b_3Y_3]. \quad (8)$$

The ratio $\frac{Q}{X_2}$ shows productivity p, which, according to equations (7) and (8) is a function of the ratio $\frac{X_1}{X_2}$. The last ratio can be considered as proxy variable of the capital per employee, the size of the enterprise measured in relation to employment X_2, the level of professional training Y_1, agglomeration economies Y_2 and distance of each prefecture from the centres of innovations Y_3. Moreover, for the primary sector, productivity is a function of the used mechanical equipment X_3 and of irrigated agricultural areas Y_4.

Taking the logarithms of the parts of equations (7) and (8) we obtain:

$$\ln p = \ln a_0 + a_1\ln(X_1/X_2) + a_2\ln X_2 + a_3\ln X_3 + b_1Y_1 + b_2Y_2 - b_3Y_3 + b_4Y_4\,; \quad (9)$$

$$\ln p = \ln a_0 + a_1\ln(X_1/X_2) + a_2\ln X_2 + b_1Y_1 + b_2Y_2 - b_3Y_3. \quad (10)$$

Following, the quantification of the determinant factors previously described and the estimation of the influence of each factor on the configuration of the final size of labour productivity in the 39 mainland prefectures of Greece (NUTS II) will be attempted. For the dependent variable we divide the annual produced added value with the average annual employment for the two sectors per prefecture. For the variable $\frac{X_1}{X_2}$ in the primary sector we estimate the ratios of agricultural area to average annual employment, while in the secondary sector we estimate the ratio of industrial horsepower to the average annual employment, taking into account the fact that data about the value of utilised capital in the secondary sector per prefecture do not exist. For variable X_2 we use the total employment for each sector, while for variable X_3 we use the amount of tractors used per prefecture. For variable Y_1 an indicator of education and professional training of population in each prefecture was used. This indicator was estimated in a previous study by Polyzos (2001). For variable Y_2 in the primary sector we use the degree of partionality of rural areas. This constitutes a metrics of scale economies, while for the secondary sector we use the total population per prefecture, assuming that it is a proxy of agglomeration economies or that the agglomeration industrial activities are proportional to the population of each prefecture. This is an assumption which for Greece is close to reality. For the agricultural sector we use for variable Y_4 the quantity of irrigated areas that indirectly depicts the existing infrastructures related to irrigation or irrigation-relevant works for each prefecture. The statistical data for estimating the variables have been obtained from NSSG (1998, 1999, 2001, 2002) or other studies (Polyzos and Petrakos, 2000; Polyzos, 2001; Polyzos and Arambatzis, 2006; Polyzos, 2006).

Finally, the crucial issue is related to the estimation of variable Y_3. This variable illustrates the distance of each prefecture from the centres of innovation, and technological knowledge production and development, or even the nodal centres of such technologies' imports from abroad. It is widely accepted that as far as Greece is concerned, these centres are Athens and Thessaloniki. In these urban centres are concentrated: 50% of the country's population, 70–80% of large-scale industry and services, the largest universities and almost all research institutes. Moreover, these cities constitute the major 'gateway' of technology (or nodes) from abroad. Thus, for estimating variable D we will use the time-distance of each prefecture from Athens and Thessaloniki, assuming that the volume of technological development that originates in Athens is three times as much as that corresponding to Thessaloniki, namely, is proportional to the population of the two cities.

Considering the above assumption, we estimate for each prefecture the distances from Athens D_{At}, from Thessaloniki D_{Th}, and, we run the model by using the distance $D = D_{At}$, as long as $D_{At} < D_{Th}$ and $D = 0.75D_{At} + 0.25D_{Th}$, provided that $D_{At} > D_{Th}$, and assuming that Thessaloniki produces the same (or competitive) technology but in a proportion of 1/3 compared to Athens. Consequently, each prefecture to which the distance from Thessaloniki is shorter than the distance from Athens, 'obtains' 25% of technological knowledge from Thessaloniki, since this is favored by the distances, and the remaining 75% from Athens. We use the road time-distances between prefectures, because the road networks constitute the prevailing means of traveling in Greece, accounting for over 90% of the total transportation transfers.

Table 2. Estimation of parameters of the factors that have an influence on the formation of productivity by using OLS

Dependent variable: $\ln p_i$

Agricultural sector				
Independent variables	Estimators of parameters	Values of *t* distribution	Significance of *t*	
(Constant)	–3.442	–5.663	0.000	$R^2 = 0.80$, adj$R^2 = 0.76$, $N = 39$
$\ln(X_1/X_2)$	0.743	7.535	0.000	
$\ln X_2$	$1.178*10^{-2}$	0.186	0.854	
$\ln X_3$	$-1.08*10^{-2}$	–0.167	0.868	
Y_1	$6.598*10^{-3}$	1.695	0.097	
Y_2	$1.867*10^{-2}$	1.294	0.203	
Y_3	$-1.10*10^{-4}$	–1.763	0.084	
Y_4	$2.860*10^{-4}$	1.431	0.161	
Secondary sector				
Independent variables	Estimators of parameters	Values of *t* distribution	Significance of *t*	
(Constant)	8.688	11.66	0.000	$R^2 = 0.56$, adj$R^2 = 0.51$, $N = 39$
$\ln(X_1/X_2)$	0.169	1.436	0.158	
$\ln X_2$	$9.720*10^{-2}$	0.729	0.443	
Y_1	$1.208*10^{-3}$	0.265	0.795	
Y_2	$1.821*10^{-6}$	1.299	0.201	
Y_3	$-1.622*10^{-4}$	–2.904	0.034	

We estimate the parameters of equations (7) and (8) by using the OLS method. The results of OLS estimation of the parameters of equations and the significance of *t* test are given in table 2. Considering the results of the estimations, we can say, in general, that the overall explanatory power, as expressed by the coefficient of determination (R^2 and R^2-adjusted), is considered to be satisfactory, given the cross-sectional type of the statistical data. The values of the estimates, in certain cases, confirm the initial expectations for a positive contribution of the determinant factors in the configuration of the productivity level, and in other cases, do not. The majority of the estimates have the expected sign but not a statistically significant effect on the dependent variables.

Not all the results and the coefficients of each independent variable will be commented on. Rather, we will focus on the coefficients of variable Y_3, which, as was mentioned before, illustrates the distance of each prefecture from the centers of innovations and technological knowledge generation and development. Both solutions yielded negative signs to the coefficient of variable Y_3. Additionally, the coefficient is statistically significant for both the equations. These results lead to the conclusion that distance plays an important role in technological diffusion and thus in regional productivity. Hence, the construction of the Egnatia Motorway is going to benefit those prefectures that improve their road-links with the prefectures of Attiki and Thessaloki, since better road infrastructure has a positive effect on productivity and thus, on competitiveness.

6. CHANGES IN TRADE FLOWS

The improvement of the interregional transportation infrastructures firstly affects trade through the changes in geographic distances and transportation cost and secondly, by altering the factor 'productivity', to the extent that this factor is influenced by the distances of individual regions from innovation centres. The temporal emergence of these two changes has not the same pace, since the transfer of new technologies from the centres to the regions as well as the adoption of new technologies by enterprises require more time to happen in comparison to the time required for medium changes in commercial transactions (Richardson, 1972, 1978; Argyris, 1991). Consequently, the total changes in trade comprise *short-term* changes that emerge immediately through the changes in transportation cost between the regions, and *long-term* change that is related to the increase of regional productivity.

For calculating the changes in trade flows Δt_i^{sr} due to reductions in interregional distances we assume a system of three regions s, s_o and r. Within this system the distance Δd^{sor} can be altered. Changes in interregional distance Δd^{sor} will result in producing direct changes in the trade flows from s_0 to r and indirect changes in trade flows from s to r, as well as changes in intraregional flows of r.

The change Δt_i^{sr} of trade flows from region s to region r, due to a change in distance d^{sor} by Δd^{sor}, will be estimated as the partial differential (where $m = 3$):

$$\Delta t_i^{sr} = \frac{\partial t_i^{sr}}{\partial d^{sor}} \Delta d^{sor} ;$$

$$\Delta t_i^{sr} = \frac{c[(E_i^s)^a (p_i^s)^b \exp(-cd^{sr})][(E_i^{so})^a (p_i^{so})^b \exp(-cd^{sor})}{\sum_{s=1}^{m}[(E_i^s)^a (p_i^s)^b \exp(-cd^{sr})]^2} \Delta d^{sor};$$

$$\Delta t_i^{sr} = ct_i^{sr} t_i^{sor} \Delta d^{sor}. \quad (11)$$

The change Δt_i^{sor} of trade flows from region s_o to region r, after the change of distance d^{sor}, will be obtained from the partial differential:

$$\Delta t_i^{sor} = \frac{\partial t_i^{sor}}{\partial d^{sor}} \Delta d^{sor}$$

$$\Delta t_i^{sor} = \frac{[-c[(E_i^{so})^a (p_i^{so})^b \exp(-cd^{sor})] - c[(E_i^{so})^a (p_i^{so})^b \exp(-cd^{sor})]^2}{\sum_{s=1}^{m}[(E_i^s)^a (p_i^s)^b \exp(-cd^{sr})]^2} \Delta d^{sor};$$

$$\Delta t_i^{sor} = -c[t_i^{sor} - (t_i^{sor})^2]\, \Delta d^{sor}. \quad (12)$$

Given a stable demand for product i within region r, a reduction in distance d^{sor} will produce the following changes in trade flows from the regions of origin (s_o *και* s) to the destination region r: (a) increase in trade flows coming from region s_o (*direct effect*), (b) decrease in trade flows from region s (*indirect effect*) and (c) decrease in trade flows from r itself (*indirect effect).*

In a system of m regions – in which k link-distances with region r have been altered, while n such link-distances remain unaltered ($k + n = m$) – each region r_k changes the trade flows to r, subject to both the change in distance between r_k and r (*direct effect*) as well as to the changes in distances between each other region and region r (*indirect effect*). The total change will be the sum of the direct and indirect change. It is not known in advance if this sum takes values below or above zero. Moreover, each region s_n alters its trade flows toward r, as a result of changes in distances between regions r_k and r (*indirect effect*).

For investigating the total change of trade flows towards region r, the total effect caused by the change in distance d^{rjr} of a random region r_j (j = 1, ..., k) to r will be examined. Bearing in mind what was mentioned before about changes in distance, we will have:

(a) The direct change of trade of region r_j to region r due to the change in distance d^{rjr}, as it derives from equation (9), will equal:

$$\Delta t_i^{rjr} = -c\Delta d^{rjr}\, [t_i^{rjr} - (t_i^{rjr})^2] > 0. \quad (13)$$

(b) The indirect changes of trade flows from regions r_k ($k \neq j$) to region r due to the change in distance d^{rjr}, as it derives from equation (8), will equal:

$$\sum_{\substack{k=1 \\ k \neq j}}^{m-n} \Delta t^{rkr} = \sum_{\substack{k=1 \\ k \neq j}}^{m-k} c\Delta d^{rjr}\, t^{rkr}\, t^{rjr} < 0. \tag{14}$$

(c) The indirect changes of trade flows from regions s_n to region r due to the change in distance d^{rjr}, as it results from using equation (11), will equal:

$$\sum_{n=1}^{m-k} \Delta t^{sns} = \sum_{n=1}^{m-k} c\Delta d^{rjr}\, t^{snr}\, t^{rjr} < 0. \tag{15}$$

The change in trade flows from region $r_{j,}$ (region $r_{j,}$ belongs to the group of regions whose link-distance to r has changed), will equal:

$$\Delta t^{rjr} = -c\Delta d^{rjr}\, [t_i^{rjr} - (t_i^{rjr})^2] + \sum_{\substack{k=1 \\ k \neq j}}^{m-n-1} [c\Delta d^{rkr}\, t^{rkr}\, t^{rjr}]. \tag{16}$$

For each region s_n that belongs to the group of regions $n = m - k$ (for these regions the link-distance with r does not change) the change in trade flows towards r will equal:

$$\Delta t^{snr} = \sum_{k=1}^{m-n} c\Delta d^{rkr}\, t^{snr}\, t^{rkr}. \tag{17}$$

Long-term changes will be the result of improvements in productivity of one or more regions. Considering a system of three regions s, s_0 and r, as well as assuming that the productivity of region s_0 changes, the changes in trade flows from regions s, s_0 (origin) towards region r (destination) will be estimated.

The change of trade flows of region s to region r by a factor of Δt_i^{sr}, due to changes in productivity Δp_i^{so}, is estimated by taking the partial differential:

$$\Delta t_i^{sr} = \frac{\partial t_i^{sr}}{\partial p_i^{so}} \Delta p_i^{so}$$

$$= \frac{[-(E_i^s)^a (p_i^s)^b \exp(-cd^{sr})][b(E_i^{so})^a (p_i^{so})^{b-1} \exp(-cd^{sor})]}{\sum_{s=1}^{m} [(E_i^s)^a (p_i^s)^b \exp(-cd^{sr})]^2} \Delta p_i^{so};$$

$$\Delta t_i^{sr} = -\mathrm{b}(\frac{\Delta p_i^{so}}{p_i^{so}})\, t_i^{sr} t_i^{sor}. \tag{18}$$

The change of trade flows from region s_0 to region r by a factor of Δt_i^{sor}, due to changes in productivity p_i^{so}, is estimated by taking the partial differential:

$$\Delta t_i^{sor} = \frac{\partial t_i^{sor}}{\partial p_i^{so}} \Delta p_i^{so} = \{[b(E_i^{so})^{\alpha} (p_i^{so})^{b-1} \exp(-cd^{sor})][\sum_{s=1}^{m} (E_i^{s})^{\alpha} (p_i^{s})^{\mathrm{b}} \exp(-cd^{sr})] -$$

$$-[(L_i^{so})^{\alpha} (p_i^{so})^{b} \exp(-cd^{sor})][b(E_i^{so})^{\alpha} (p_i^{so})^{\mathrm{b}} \exp(cd^{sor})\}/[\sum_{s=1}^{m} (E_i^{s})^{\alpha} (p_i^{s})^{b}$$

$$\exp(-cd^{sr})]^2 \Delta p_i^{so};$$

$$\Delta t_i^{sor} = b(\frac{\Delta p_i^{sor}}{p_i^{so}})[t_i^{sor} - (t_i^{sor})^2]. \tag{19}$$

Given a known as well as stable demand for product i within region r, and assuming a system consisting of three regions s, s_o and r, the improvement in productivity of region s_o, will produce the following changes in trade flows towards r: (a) increase in trade flows from region s_o (*direct effect*), (b) decrease in trade flows from s (*indirect effect*) and (c) decrease in trade flows from r itself (*indirect effect*). It is also obvious that respective changes in the productive sectors of each region in a direction of increasing production in s_o and decreasing production in s and r will be induced.

In a system of m regions – in which k regions improve their productivity, while the productivity of the remaining regions n stays unchanged – each region r_k alters the trade flows towards r, subject to both the change in productivity itself (*direct effect*) and the change in productivity of the remaining regions (*indirect effect*). The total change will be the sum of the direct and indirect effects. It should be said, that it is not known in advance if this sum takes values below or above zero. Moreover, each region s_n alters its trade flows toward r, as a result of changes in productivity of regions r_k (*indirect effect*).

For investigating the total change of trade flows towards the region r, the total effect caused by the change in productivity of a random region r_j belonging in the group of the regions whose productivity changes (j = 1, ..., k) will be examined. The following cases can be distinguished:

(a) The direct change of trade of region r_j to the region r due to the change in productivity p_i^{rj}, comes from equation (16) and equals:

$$\Delta t_i^{rjr} = b(\frac{\Delta p_i^{rj}}{p_i^{rj}})\ [t_i^{rjr} - (t_i^{rjr})^2] > 0. \qquad (20)$$

(b) The total indirect changes in trade flows from region r_k ($k \neq j$) to the region r, due to changes in productivity p_i^{rjr} equal:

$$\sum_{\substack{k=1 \\ k \neq j}}^{m-n} \Delta t^{rkr} = \sum_{\substack{k=1 \\ k \neq j}}^{m-n-1} [-b(\frac{\Delta p_i^{rj}}{p_i^{rj}})t_i^{rkr} t_i^{rjr}] < 0. \qquad (21)$$

(c) The total indirect changes in trade flows from region s_n to region r, due to changes in productivity p_i^{rjr}, result from the equation (18) and equal:

$$\sum_{n=1}^{m-k} \Delta t^{snr} = \sum_{n=1}^{m-k} [-b(\frac{\Delta p_i^{rj}}{p_i^{rj}})\ t_i^{snr} t_i^{rjr}] < 0. \qquad (22)$$

The change in trade flows for each region r_j, (region r_j, belongs to the group of regions whose productivity has changed), results from equations (20) and (21) and equals:

$$\Delta t_i^{rjr} = b(\frac{\Delta p_i^{rj}}{p_i^{rj}})[t_i^{rjr} - (t_i^{rjr})^2] + \sum_{\substack{k=1 \\ k \neq j}}^{m-n-1} [-b(\frac{\Delta p_i^{rkr}}{p_i^{rkr}})t_i^{rjr} t_i^{rkr}]. \qquad (23)$$

For every region s_n that belongs to the group of $n = m - k$ regions (for these regions productivity does not change), the change of trade flows towards r results from equation (22) and equals:

$$\Delta t^{snr} = \sum_{k=1}^{m-n} [-b(\frac{\Delta p_i^{rk}}{p_i^{rk}})\ t_i^{snr} t_i^{rkr}]. \qquad (24)$$

The estimation of trade flows to region *r* is performed under the assumption that the total demand of *r* for commodity *i* remains unchanged. Finally, as has already been mentioned, for calculating the total changes, it is essential that we estimate both the short-term and the long-term changes in the regions. To achieve this, it may be necessary to use various combinations of the above equations, each time depending on the changes at hand.

7. ESTIMATION OF CHANGE IN TRADE FLOWS AFTER THE CONSTRUCTION OF THE EGNATIA MOTORWAY

Next, based on the above equations and on the coefficients previously calculated, we will estimate short-term and long-term changes. These changes will emerge in the Greek prefectures after the construction of the Egnatia Motorway. The results of the estimations are shown in tables 3 and 4.

Table 3. Estimations of changes in agricultural and mining products in the Greek prefectures

Prefecture	Agricultural products		Mining products	
	short-term changes	long-term changes	short-term changes	long-term changes
1	2	3	4	5
Attica	–0.022	–0.034	–0.064	–0.067
Aitolia/Akarnania	–0.057	–0.078	–0.014	–0.016
Boeotia	–0.021	–0.033	–0.028	–0.029
Euboea	–0.015	–0.025	–0.064	–0.068
Evritania	0.031	–0.038	–3.107	–3.221
Fthiotis	–0.029	–0.049	–0.154	–0.163
Fokis	–0.065	–0.187	–3.039	–3.158
Argolis	–0.008	–0.017	–0.125	–0.130
Arcadia	–0.045	–0.072	–0.075	–0.078
Achaea	–0.030	–0.042	–0.081	–0.084
Ilia	–0.019	–0.035	–0.161	–0.167
Corinth	–0.029	–0.044	–0.090	–0.093
Laconia	–0.009	–0.029	–0.157	–0.163
Messinia	–0.018	–0.029	–0.062	–0.064
Elevkas	0.551	0.374	0.451	0.417
Arta	–0.037	–0.075	0.102	0.084
Thesprotia	0.248	0.236	0.046	0.045

Table 3 (cont.)

1	2	3	4	5
Ioannina	0.170	0.147	–0.050	–0.055
Preveza	0.131	0.114	0.065	0.059
Karditsa	–0.046	–0.073	–0.847	–0.884
Larisa	–0.028	–0.050	–0.198	–0.213
Magnesia	–0.160	–0.243	–0.088	–0.095
Trikala	–0.033	–0.056	–0.222	–0.231
Grevena	0.442	0.543	0.259	0.303
Drama	0.215	0.536	0.788	0.890
Imathia	0.022	0.063	–0.034	–0.020
Thessaloniki	–0.013	–0.041	0.003	–0.001
Kavala	0.194	0.375	0.554	0.634
Kastoria	–0.060	–0.139	–2.115	–2.203
Kilkis	–0.063	–0.155	0.134	0.121
Kozani	0.148	0.227	–0.009	–0.008
Pella	–0.021	–0.037	–0.055	–0.064
Pieria	–0.088	–0.145	–0.100	–0.116
Serrai	–0.049	–0.084	0.022	0.002
Florina	–0.093	–0.153	–0.014	–0.014
Khalkidiki	–0.111	–0.181	–1.323	–1.656
Evros	–0.052	–0.009	0.479	0.496
Xanthi	0.327	0.541	1.453	1.516
Rodopi	0.172	0.265	3.193	3.275

Table 4. Estimations of changes in industrial and chemical products and construction materials in the Greek prefectures

Prefecture	Industrial and chemical products		Construction materials	
	Short-term changes	long-term changes	short-term changes	long-term changes
1	2	3	4	5
Attica	–0.018	–0.023	–0.063	–0.078
Aitolia/Akarnania	–0.020	–0.026	–0.030	–0.035
Boeotia	–0.024	–0.030	–0.005	–0.008
Euboea	–0.012	–0.016	–0.012	–0.016
Evritania	–0.056	–0.931	1.085	0.742

Table 4 (cont.)

1	2	3	4	5
Fthiotis	–0.072	–0.091	–0.030	–0.041
Fokis	–0.030	–0.060	0.431	0.288
Argolis	–0.010	–0.014	0.002	–0.0006
Arcadia	–0.009	–0.018	0.011	0.004
Achaea	–0.018	–0.022	–0.021	–0.026
Ilia	–0.008	–0.015	0.051	0.027
Corinth	–0.018	–0.023	8.48E-05	–0.007
Laconia	–0.005	–0.017	0.032	0.020
Messinia	–0.008	–0.013	0.005	0.001
Levkas	0.368	0.310	9.298	8.588
Arta	0.002	–0.009	0.048	0.025
Thesprotia	0.372	0.367	0.089	0.086
Ioannina	0.170	0.158	0.101	0.089
Preveza	0.166	0.152	0.195	0.180
Karditsa	–0.165	–0.224	–0.019	–0.046
Larisa	–0.087	–0.121	–0.042	–0.056
Magnesia	–0.074	–0.099	–0.040	–0.060
Trikala	–0.076	–0.102	–0.028	–0.035
Grevena	1.000	1.109	0.537	0.583
Drama	0.042	0.314	–0.064	0.054
Imathia	0.036	0.078	0.081	0.123
Thessaloniki	–0.004	–0.016	0.028	0.004
Kavala	0.078	0.147	0.002	0.078
Kastoria	–0.673	–0.900	0.046	0.016
Kilkis	–0.058	–0.103	0.008	–0.025
Kozani	0.074	0.111	0.126	0.164
Pella	–0.023	–0.041	–0.041	–0.065
Pieria	–0.063	–0.116	–0.045	–0.083
Serrai	–0.087	–0.121	–0.104	–0.145
Florina	–0.073	–0.101	–0.018	–0.037
Khalkidiki	–0.061	–0.100	–0.069	–0.120
Evros	0.043	0.091	–0.146	–0.119
Xanthi	0.189	0.344	0.057	0.121
Rodopi	0.383	0.475	0.219	0.264

From these tables, it can be seen that there are prefectures exhibiting an increase in their trade flows concerning certain categories of commodities as well as a decrease in their trade flows concerning other commodities. Additionally, we observe that changes in the short term due to reduced interregional distances account for about 60–70% of the total change. This change is the sum of changes due to distance reduction and due to productivity improvements.

It is apparent that certain prefectures improve their position in the system while some others worsen their position. This is due to the fact that the changes estimated previously have a redistributive character and the final sum that will result will equal zero. It is also apparent that the change in trade flows will influence the level of production of each prefecture and the level of regional growth. The final repercussions that will be caused by the Egnatia Motorway, according to the proposed model, depend on (a) the comparative advantage portrayed in the productivity of each prefecture, (b) the reduction in distance of each prefecture from the prefectures that constitute the suppliers of products that the prefecture produces.

The final results suggest that the prefectures deriving an advantage are those that the Egnatia Motorway crosses, namely the prefectures of Thesprotia, Ioannina, Preveza, Grevena, Drama, Kavala, Xanthi and Rodopi. However, there are prefectures crossed by the Egnatia Motorway, as are the prefectures of Evros, Pieria, Kilkis and Thessaloniki, which show a reduction in trade flows concerning some or all sectors. The prefectures of Central and Southern Greece show, as was expected, a reduction in trade flows and hence the construction of the Egnatia Motorway is expected to have negative effects on their economy to the extent that their economy depends on trade.

8. CONCLUSIONS

The evaluation of the impacts created by the Egnatia Motorway – and in particular the assessment of the motorway spatial effects must be approached, not only in terms of transport infrastructure and the functioning of the road network, but also in relation to the economic, social and spatial cohesion as well as in the light of regional development in general. In such a context, the evaluation of these infrastructures should involve the estimations of the changes in the interregional trade and the regions' economic development. The Egnatia Motorway is expected to enhance the geopolitical position of Greece in Europe, the Balkans, the Mediterranean Sea and the countries of the Black Sea in order to reduce disparities of regional development in Europe.

This paper provides an ex ante assessment of the short-and long-term changes in interregional trade flows between Greek prefectures, resulting from the construction of the Egnatia Motorway. The construction of the Egnatia Motorway started in 1998 and 1999. According to some estimation, it will probably finish in the year 2009. The main statistical data that were used correspond to 1993–2000, namely a period during which the construction of the project began. After the motorway is constructed, an ex post evaluation of the resultant changes in trade flows can verify the accuracy of the suggested estimations performed above.

Another thing that should be said concerns the competitiveness of interregional infrastructures. Parallel to the Egnatia Motorway construction, a large number of important transregional road infrastructures is under way (like the PATHE Motorway, the Ionian Motorway, etc.). These infrastructures can be seen as being 'competitive' to the Egnatia Motorway. Thus, in the coming years, the spatial changes that will emerge in Greek prefectures will be the result of the influence of all works under construction. The positive or negative changes that the Egnatia Motorway will cause might decrease or increase in magnitude because of other infrastructures' effects.

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