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INTERREGIONAL TRANSPORT INFRASTRUCTURES AND REGIONAL DEVELOPMENT: A METHODOLOGICAL APPROACH

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Abstract

Transport infrastructures and economic development lie under a symbiotic relation, which is both theoretically and empirically evident and studied, at all levels of geographical and administrative scale. Building on the conceptual framework theoretically discussed in a previous work of the authors, this paper goes beyond current approaches and develops an integrated methodological framework for an ex-ante quantitative assessment of the (direct and indirect) effects of interregional transport infrastructures on spatial economies. To do so, it first applies a brief literature review to the main relevant methodologies, next describes the proposed methodological framework, and finally discusses each framework's component separately. The proposed methodology builds on an input-output (I-O) model conceptualization and contributes to the current literature by (i) integrating direct, indirect, and induced economic impacts; (ii) separating distributive and generative effects for each region; (iii) providing individual estimations based on spatial interdependence or econometric models; (iv) distinguishing cases for trade coefficients' estimation; (v) investigating the impact on the choice of the location of enterprises' establishment; (vi) assessing the effects of transport infrastructure on tourism; and (vii) incorporating technology "diffusion" from centers to regions. The overall approach is broadly applicable and can motivate empirical research, by providing insights into estimating the contribution of transportation infrastructures' construction to a regional economy, along with a decision-making tool for transport policy, regional planning, and economic growth.

Keywords: transport infrastructures, regional development, economic development, transport economics, transport policy, regional policy.

1. INTRODUCTION

In a previous article (Polyzos and Tsiotas, b2020) the relationship between transport infrastructure and regional development was analyzed in a theoretical framework. In this article, a methodological approach is formulated for an ex-ante quantitative estimation of effects brought about by interregional transport infrastructures in the economy of those regions directly or indirectly affected by these infrastructures. This quantitative assessment is particularly important for the evaluation of transport infrastructures and especially for the consideration of their effects on regional development in an appraisal process (Venables et al. 2014). In general, the evaluation of the contribution of transport infrastructures on regional development is particularly useful for effective regional policy and planning, because infrastructures are an important "tool" for the development of less developed regions (Fayman et al., 1995; Venables et al., 2014). The importance of transport infrastructures for economic development is widely acknowledged and well documented in the literature since they can be represented as one factor in a region's production function (He and Duchin, 2009). The transportation infrastructure is considered to be a key instrument in promoting economic development (Tsiotas and Polyzos, 2015; Tsiotas and Polyzos, 2018a). Moreover, the interregional transport infrastructures influence the geographic location of production activities, as well as the spatial balance and the interregional interdependence (Rietveld, 1994; Tsiotas and Polyzos, 2018b; Polyzos and Tsiotas, 2020, An et al., 2022).

The ex-ante quantitative estimation of the regional economic impacts resulting from the construction and operation of interregional transport infrastructures shows some particularities compared to the impact assessment of other infrastructures. The particularities of the ex-ante assessment are due to the more general change in interregional economic relations brought about by the reduction of the interregional distance or the cost of connecting certain regions (Rietveld, 1994; Polyzos and Tsiotas, 2020). This reduction results in the appearance of direct effects in the regions, where the infrastructures are constructed, and indirect effects in the rest of the regional system, with an intensity that decreases according to the distances. Also, the particularities of ex-ante estimation are due to the difficulty of long-term determination of the "direction" in which some of the regional changes will move, i.e. whether or not they favor the improvement of the performance of the regional economy (Rephanm, 1993). Transport infrastructures are often seen as an effective means to boost the regional economy by improving transport links both within the target region and to or from other regions (Rietveld, 1994; Polyzos and Tsiotas, 2020; An et al., 2022). However, interregional transport infrastructures possibly cause the "two-way street" problem. In other words, the reduction of interregional distances and corresponding transport costs increases spatial competition and may favor already-developed regions at the expense of less-developed ones. For this reason, any policy to implement transport investments to support regional development would require very careful assessment (Kasikoen et al., 2019).

Taking as a starting point the great importance of transport infrastructure for regional and local development, the purpose of this paper is to provide a conceptual framework for a quantitative ex-ante estimation of changes in the regional economy coming from the interregional transport infrastructures operation. In the next section, a brief reference to the main methodologies that have been developed in the literature for the quantitative assessment of interregional transport infrastructures in the economies of the regions that influence directly or indirectly is made. In the third section, the framework of the proposed approach is described, while in the fourth section, each element of the approach is analyzed. The fifth section follows, where the conclusions coming from the preceding analysis are formulated.

1. LITERATURE REVIEW

The economic impacts of new transport infrastructure have become an important issue for policymakers. For this reason, there are multifaceted scientific discussions and relevant approaches to the contribution of new transport infrastructure to regional development, as well as the adequacy of this strategy to promote economic development. The main methodologies, which have been developed and applied internationally for the quantitative assessment of the effects of transport infrastructures on regional development, are based on multi-equations models. These methodologies can be distinguished into econometric and Input-Output models. These methodologies emerged in the literature mainly in the 1980s and 1990s, while later, the interest of researchers in the quantitative assessment of the relationship between transport infrastructures and regional development appears relatively limited.

In econometric or statistical models, transport infrastructures are conceived as a productive factor, while the measure of their relationship with regional productivity (or total production) is usually a main research task. In other words, transport infrastructure can be considered as a stock of a certain type of capital, available in a region or a country, and can participate as a variable in a region's or country's production function (Aschauer, 1989; Munnell, 1990; Arbues et al., 2015; Mohmand et al., 2017; Cigu et al., 2019). These approaches can be seen as general, as not specialized for the quantitative analytical assessment of all the results caused to each region by the construction and operation of interregional transport infrastructures. Amano and Fujita (1970) suggested a pioneer model for the estimation and comparison of regional and national economic effects of several alternative plans for a particular nationwide transportation facility. This model was based on an expanded Moses interregional Input – Output (I-O) model and only considers changes in the technological transport sector's coefficients (as defined in the I-O methodology) due to a reduction in interregional transport costs. Liew and Liew (1984, 1985) also developed a multiregional model focusing on the price change as a result of changes in transport costs. Specifically, this model uses a maximizing problem of aggregate profit of the private sector as a whole in a country, to estimate the amounts of regional sectoral output as well as interregional trade flows. The assumption that outputs, prices, and interregional trades for each region and industrial sector are determined in a very centralized manner, from the viewpoint of maximizing an aggregate profit in a society, can be seen as unrealistic in a modern decentralized capitalist economy (Sasaki et al., 1987). To overcome the limitations of Liew and Liew's model, Sasaki et al. (1987) suggested a model in which prices and outputs are determined not simultaneously but step-wisely. However, in the models of Liew and Liew

(1984, 1985) and Sasaki et al. (1987), the main emphasis is given to the process of estimating the general change in technological coefficients, assuming that a small decrease or even increase in transport cost will cause sequential changes to the "inputs" accompanied with substitution effects between the productive sectors of the economy. In another model, Lin and Hanson (1976) combine the I-O methodology with linear programming to calculate the total change in regional output, which is the result of a decrease in interregional transport costs. Further late approaches also build on I-O analysis. For instance, Pant et al. (2011) used a risk-based Multi-Regional Inoperability Input-Output Model to describe the interdependent adverse effects of disruptive events on interregional commodity flows resulting from disruptions at an inland port terminal. Ishikuraa (2020) proposed a methodology based on a spatial computable general equilibrium (SCGE) model taking into account the asymmetric aspects of trade gateway region explicitly. The model describes the role of the export and import sector in the trade gateway region, which does not exist in other hinterland regions. Vukic et al. (2021) used I-O analysis to estimate the multiplier effects of the transport sector and to identify changes and trends over a while.

As is evident by the previous review, these recent methodologies are general, to the extent that they apply to all transport infrastructures and do not exclusively specialize in interregional transport infrastructures. They also ignore changes in business location, tourism, business productivity, or production capabilities improvements, and can apply to calculate the effects of any "intervention" causing a reduction in interregional transportation costs. Going beyond these approaches, this article proposes a general methodological framework for the quantitative analysis of the effect of interregional transport infrastructures on regional development and describes an integrated methodology, practically applicable to a wide range of problems. The proposed approach can be used for regional analysis and facilitate better or more efficient planning of infrastructures through their appraisal, to satisfy the economic and regional policy objectives.

2. THE PROPOSED METHODOLOGICAL FRAMEWORK

In the proposed methodology, we attempt to incorporate all economic impacts with a generative or distributive character that emerge in the regions after the construction of interregional transport infrastructures. Also, we provide the equations (math expressions) for calculating the final changes in the product of each. For the sake of clarity, we define as "generative" the effects that "produce" a positive change in the economic indicators of all regions, while "distributive" those causing a positive or negative change in the economic indicators. In other words, "generative" effects drive growth, whereas distributive effects spatially "redistribute" the growth claiming the total sum of such changes to be zero (Rietveld, 1994; Polyzos and Tsiotas, 2020).

The proposed methodology can apply to cases of any kind of interregional transport infrastructure, provided that the included equations are accordingly specialized. The proposed methodology builds on input-output (I-O) tables, which are considered the "core" of the approach. These tables enable us to calculate the direct effects on the economies of the regions through the change, due to a reduction in generalized transport costs, of inter-sectoral and inter-regional transactions with the change of trade flows, technological coefficients, and the vector of added value or final demand vector (Polyzos and Sofios, 2008; Miller and Blair, 2009). Also, these tables allow us to incorporate exogenously calculated indirect or induced effects through the positive or negative change they cause in the final demand vector for each region.

The main features and the most important differences of the proposed methodology from those mentioned in the previous section are:

- The aforementioned methodologies use input-output tables to measure mainly direct economic impacts and generally refer to transport infrastructure. The proposed methodology concerns interregional transport infrastructure and integrates direct, indirect, and induced economic impacts (Polyzos and Tsiotas, 2020).
- The proposed methodology proceeds with a clear separation of distributive and generative effects for each region. In this way, the overall result is assigned to each region and provides the possibility to evaluate alternative solutions for a transportation project or a transportation infrastructure construction program, using, among other criteria, the predicted effects on regional development.
- In the proposed methodology, we apply individual estimations with spatial interdependence or econometric models. The "calibration" of these models requires empirical investigation, therefore facilitating capturing of the reality and the importance of each factor in the final result with the existing economic conditions.
- For trade coefficients estimation, a different methodology is proposed, in which the productivity of each sector in each region is integrated, as a key criterion of regional competitive advantage.
- The impact on the choice of the location of enterprises' establishment is investigated, taking into account the most important factors, which influence the spatial choices of entrepreneurs.
- The estimation of the effects of transport infrastructure on tourism is incorporated.
- The "diffusion" of technology from the production and development centers to the regions is incorporated and the more general changes are quantified, which it brings to the economies of the regions either indirectly in trade through the improvement of productivity, or directly with the increase of the produced product in the regions.

A general framework of the proposed methodology and the included steps are shown in Figure 1. As shown in Figure 1, the generative effects include:

- The increase of the consumer surplus in the regions favored by the infrastructure, which results from the direct benefits of the users of the infrastructure and indirectly due to the reduction of the prices of the products, follows the reduction of the transport costs. This increase is transferred as a positive change in the final demand vector and an equal change in the added value vector.
- The change of the technological coefficients of the transport sector in the corresponding table of the I-O methodology (change of the row and column of the table of technological coefficients referred to the transport sector).
- The change in output in the regions, results from the improvement of average productivity due to the better diffusion of technology to the regions.

The distributive effects include:

- The change in inter-regional trade flows for each commodity, is due to a reduction in "frictional resistance" between regions.
- The change in the attractiveness of the regions for the establishment of new economic activities, as well as the location of businesses and activities, which exclusively serve the transport infrastructure, the circulating vehicles, and their passengers.
- The change in tourist attractiveness and the tourist volume of visitors received by each region

The basic assumptions of the model are summarized as follows:

- The reduction of transportation costs cannot affect the production process in companies and create substitution effects between the remaining inputs. Therefore, apart from the technological coefficients of the transport sector, as they are defined in the I-O Analysis, the other coefficients do not change and the substitution effects, which may appear in the long term due solely to transport costs, are small to negligible.
- The transport sector operates in a perfectly organized competitive economic system, which ensures the "transfer" of the overall saving benefit due to the reduction of transport costs to the periphery and not its stay as a positive increase in the total profit of the sector
- The change in demand, shown in the model, is solely due to the change in generalized transportation costs that create direct, indirect, and induced effects.
- No other transport infrastructures are constructed in the short term in other regions, which would be "competitive" with the infrastructure under study and thus affect the magnitude of both direct and indirect impacts.

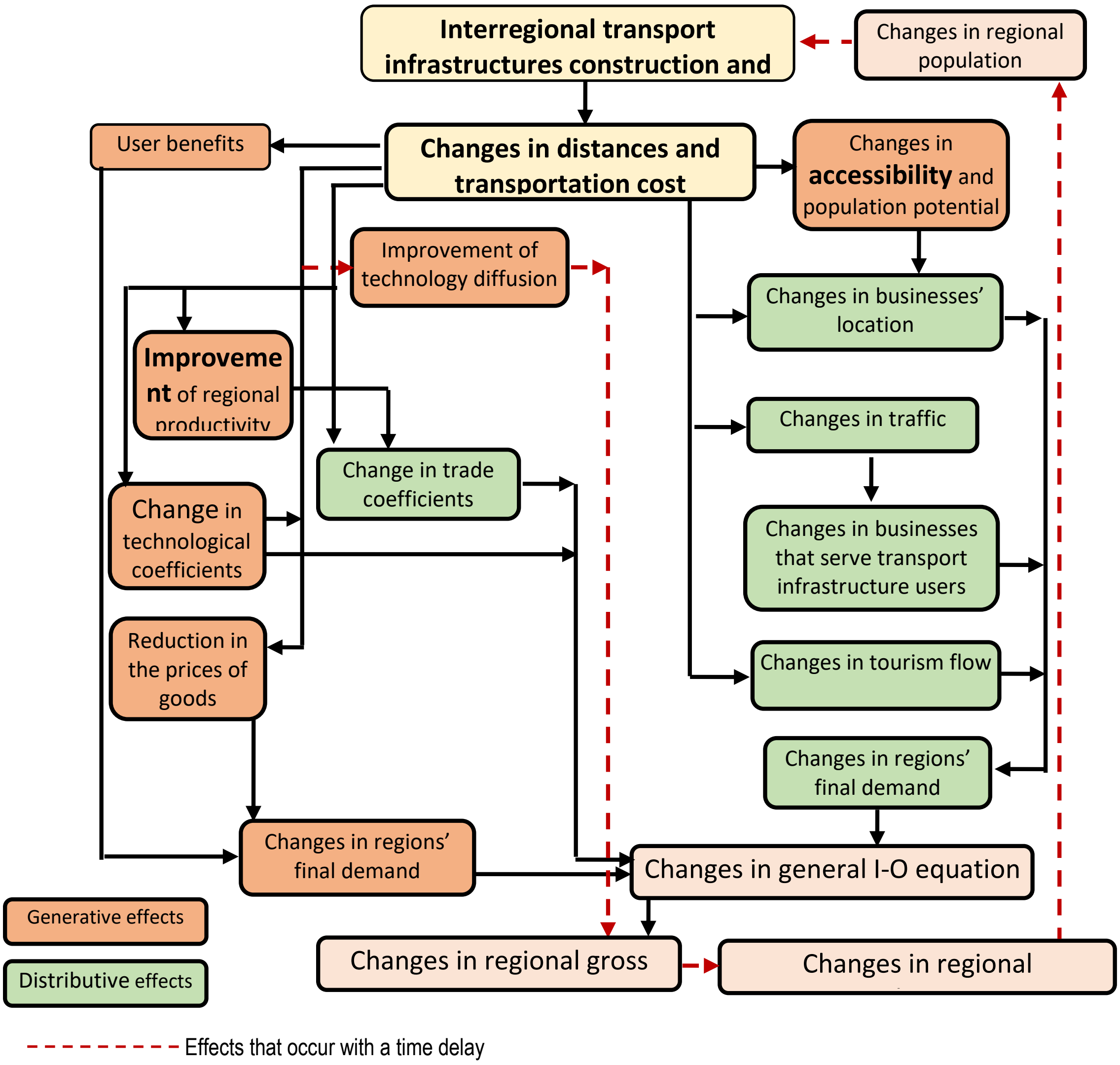

FIGURE 1 - A GENERAL FRAMEWORK AND THE BASIC STEPS OF THE PROPOSED METHODOLOGY

3. ANALYSIS OF THE PROPOSED METHODOLOGY

3.1. User benefits

The estimation of user benefits B_U^r for region r can be made by grouping the moving vehicles V_{rs} from region *r* to *s* into *k* categories according to the transportation cost and using the equation:

$$B_U^r = \sum_{s=1}^{m} [\Delta c_1^{rs} V_1^{rs} + \Delta c_2^{rs} V_2^{rs} + .. + \Delta c_k^{rs} V_k^{rs}] \quad (1)$$

Transport costs, in addition to fuel costs and other operating costs of vehicles, can include the benefit of time, which is saved due to the reduction of distances, but also the costs saved from the reduction of traffic accidents using equations found in the relevant literature (Kockelman et al., 2013). The application of equation (1) requires the existence of an "origin-destination" survey of vehicles at an appropriate geographical scale and a distinction of vehicles into categories.

3.2. Interregional distances, technology diffusion, and productivity

The level of productivity in each region 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 labor, an increase in productivity of our economic system by technological means is possible (Bronzini and Piselli, 2009; Comin and Mestieri, 2014). The construction of interregional transport infrastructures will change the distances of regions and enterprises from technology and innovation production centers (Rietveld, 1994; Polyzos and Tsiotas, 2020). These distances influence the average regional productivity because the spatial diffusion of technology, information, and technological knowledge is favored. In most countries, the interregional comparison of productivity (gross output or 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 production values.

For calculating the relation between "interregional distance" and "regional productivity" the following Cobb-Douglas-type general not-homogenous production function can be used:

$$Q = a_0 \prod_{i=1}^{n} X_i^{a_i} \exp[\sum_{j=1}^{m} b_j Y_j] \quad (2)$$

Where: Q is the output of each productive sector, X_i and Y_j are factors of production or factors that determine the level of produced commodities, and α_o, α_i, and b_j are coefficients which show the elasticity of each factor.

Depending on the productive sector under consideration, the appropriate production factors should be used. Thus, for the secondary economic sector, the following production function can be used:

$$Q=\alpha_0 K^{a1} L^{a2} \exp[b_1(\text{edu})+b_2(\text{scal})+b_3(\text{urb})-b_4(\text{dist})] \quad (3)$$

Where: K is the used capital, L is the total employment, *edu* is an indicator of the employers' level of training and education, *scal* is an indicator of scale economies, *urb* is an indicator of urbanization, *dist* is the time-distance of regions from technological centers.

For the other productive sectors, similar production functions can be formulated. For example, for the primary sector productivity as an independent variable, the right side of equation (3) may additionally be used mechanical equipment and irrigated agricultural areas (Polyzos and Arabatzis, 2006). The construction and operation of interregional transport infrastructure will change the factor *dist* in the equation (3). Dividing the members of equation (3) by L we obtain the next equation:

$$\frac{Q}{L} = a_0 (\frac{K}{L})^{a1} L^{a1+a2-1} \exp[\mathrm{b}_1(\mathrm{edu}) + \mathrm{b}_2(\mathrm{scal}) + \mathrm{b}_3(\mathrm{urb}) - \mathrm{b}_4(\mathrm{dist})] \quad (4)$$

The ratio $\frac{Q}{L}$ shows labor productivity p, which in each productive sector i in each region r will be given by the next equation:

$$p_i^r = a_0 (\frac{K_i^r}{L_i^i})^{a1} (L_i^r)^{a1+a2-1} \exp[\mathrm{b}_1(\mathrm{edu}_i^r) + \mathrm{b}_2(\mathrm{scal}_i^r) + \mathrm{b}_3(\mathrm{urb}^r) - \mathrm{b}_4(\mathrm{dist}^r)] \quad (5)$$

The change in productivity resulting from the change in distances Δ(distr) will be estimated from the equation:

$$\Delta p_i^r = p_i^r b_4 \Delta(\mathrm{dist}^r) \quad (6)$$

Assuming that employment is unaffected by the change in productivity, the increase in output resulting from the productivity improvement can be calculated from the partial differential:

$$\Delta Q_i^r = (\frac{\partial Q_i^r}{\partial p_i^r}) \Delta p_i^r \quad (7)$$

Taking into account the relation $Q_i^r = \Delta p_i^r L_i^r$ and combining relations (6) and (7) we obtain the relation:

$$\Delta Q_i^r = L_i^r p_i^r b_4 \Delta(dist^r) \quad (8)$$

Similar calculations can be made to estimate the productivity of capital.

3.3. Change in trade coefficients

The models developed to estimate interregional trade flows T^{sr} typically incorporate "supply" variables X_s for producing or exporting regions, Y_r variables for commodity importing regions, and variables that shape "frictional resistance" variables with interregional distances more important D^{sr} or transport cost (Hewings et al., 2004; Sargento et al., 2012; Liu et al., 2015). A general form of the models can be given by the equation:

$$T^{sr} = f\left(X_s,\ Y_r,\ D^{sr}\right)\ \left(s \neq r = 1,\ 2,\ 3,\ ..m\right),\ where\ \frac{\partial f}{\partial X_s} > 0, \frac{\partial f}{\partial Y_r} > 0, \frac{\partial f}{\partial D^{sr}} < 0 \quad (9)$$

The common practice of many methodologies for calculating interregional trade flows is to incorporate production costs and transport costs for each product group transported (Sasaki et al., 1987; Polyzos, 2009; Miller and Blair, 2009). This requires accurate knowledge of production costs and final prices for each production sector by region, which is difficult, especially for countries without the required statistical organization. It should be noted that, in the multiregional I-O model, the trade coefficient t_i^{sr} is used (where s, and r are the regions of origin and destination respectively for i productive sector), which is defined as the quotient of the purchases of i originating from the region s about the set of markets of i in region r (Polyzos and Sofios, 2008; Miller and Blair, 2009). Otherwise, the trade coefficient is defined by the equation:

$$t_i^{sr} = \frac{\mathrm{T}_\mathrm{i}^\mathrm{sr}}{\sum_{s=1}^{m} \mathrm{T}_\mathrm{i}^\mathrm{sr}} \tag{10}$$

It is proposed the trade coefficient t_i^{sr} be estimated by the formula:

$$t_i^{sr} = \frac{(\mathrm{E}_\mathrm{i}^\mathrm{s})^c (p_i^s)^e (M^r)^h \exp(-gd^{sr})}{\sum_{s=1}^{m} (\mathrm{E}_\mathrm{i}^\mathrm{s})^c (p_i^s)^e (M^r)^h \exp(-gd^{sr})} \tag{11}$$

Where: E_i^s is the employment in region s in sector i, p_i^s is the productivity in region s in sector i, M^r is a “mass” of consumption in region *r*, which can be represented by its population or GDP, d^{sr} is the distance or the transportation cost between *s* and *r*. This equation contains calculations for parameters *c*, *e*, *h*, and *c*, while the existing statistical data for the variables E_i^s, p_i^s, M^r and d^{sr} are satisfactory at a regional or prefectural level. The main advantage of the proposed model derives from the incorporation of productivity as one of the determinant factors of trade. According to the above, the construction of transportation infrastructures in addition to distance or transportation cost influences the productivity of enterprises, because it encourages spatial diffusion of technology and the adoption of more efficient methods of production.

The construction or improvement of an interregional transport infrastructure firstly affects trade through the changes in geographic distances and transportation costs and secondly, by changing the factor “productivity”, to the extent, that this factor is influenced by the distances of individual regions from technology and innovation centres.

The temporal emergence of these two changes has not the same pace, since the transfer of new technologies and innovations 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 changes in commercial transactions (Geroski, 2000; Foster and Rosenzweig, 2010). Consequently, the total changes in trade can be distinguished into "*short*-term" which emerges immediately through the changes in transportation costs between the regions, and "*long*-term" which is related to the increase of regional productivity.

(a) Short–term changes

For calculating the changes (Figure 2) in trade coefficient Δt_i^{sr} due to reductions in interregional distances we assume firstly a system of three regions s, s_o, and r, in which the distance d^{sor} is changed (decreases). Changes in interregional distance d^{sor} will result in producing direct changes in the trade flows from s_o to *r* and indirect changes in trade flow from *s* to *r*, as well as changes in intraregional flows of r.

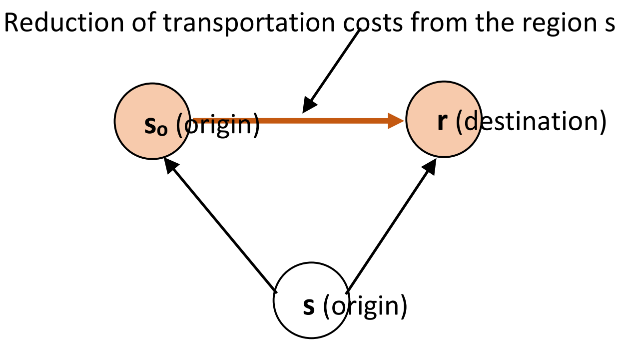

FIGURE 2 - REDUCTION (OR CHANGE) OF TRANSPORTATION COSTS FROM THE REGION S TO REGION S

- The change Δt_i^{sr} of trade coefficients related to 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):

$$\Delta t_i^{sr} = \frac{\partial t_i^{sr}}{\partial d^{sor}}\Delta d^{sor} = \frac{g[E_i^{s})^c (p_i^s)^e (M^r)^h \exp(-gd^{sr})][E_i^{so})^c (p_i^{so})^e (M^r)^h \exp(-gd^{sor})]}{\sum_{s=1}^{m}[(E_i^{s})^c (p_i^s)^e (M^r)^h \exp(-gd^{sr})]^2}\Delta d^{sor}$$

$$\Delta t_i^{sr} = g t_i^{sr} t_i^{sor} \Delta d^{sor} \qquad (12)$$

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

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

$$= \frac{[-g[(E_i^{so})^c (p_i^{so})^e (M^r)^h \exp(-gd^{sor})] - g[(E_i^{so})^c (p_i^{so})^e (M^r)^h \exp(-gd^{sor})]^2}{\sum_{s=1}^{m}[(E_i^{s})^c (p_i^s)^e \exp(-gd^{sr})]^2}\Delta d^{sor}$$

$$\Delta t_i^{sor} = -g[t_i^{sor} - (t_i^{sor})^2]\,\Delta d^{sor} \qquad (13)$$

Given a stable demand for a 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 and *s*) to the destination region *r*:

(a) increase in trade flows coming from a 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).

Generalizing the above and assuming a system of *m* regions, in which *k* link-distances with region *r* have been changed, while *n* such link-distances remain unchanged ($k+n=m$), 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 overall 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 coefficients related to trade flows from region *s* to 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 changes of trade coefficients related to the change of trade flows of region rj to region r due to the change in distance d^{rjr}, as it derives from equation (13), will equal:

$$\Delta t_i^{rjr} = -g\Delta d^{rjr}\,[t_i^{rjr}-(t_i^{rjr})^2] > 0 \tag{14}$$

(b) The indirect changes of trade coefficients related to trade flows from regions rk ($k \neq j$) to region r due to the change in distance d^{rjr}, as it derives from equation (12), will equal:

$$\sum_{\substack{k=1\\k\neq j}}^{m-n} \Delta t^{rkr} = g\Delta d^{rjr}\, t^{rkr}\, t^{rjr} < 0 \tag{15}$$

(c) The indirect changes of trade coefficients related to trade flows from regions sn to region r due to the change in distance d^{rjr}, as it results by using equation (12), will equal:

$$\sum_{n=1}^{m-k} \Delta t^{sns} = \sum_{n=1}^{m-k} g\Delta d^{rjr} t^{snr} t^{rjr} < 0 \tag{16}$$

The change in trade coefficients related to trade flows from region r_j, (region r_j belongs to the group of regions whose link distance to *r* has changed), will equal:

$$\Delta t^{rjr} = -g\Delta d^{rjr}\,[t_i^{rjr}-(t_i^{rjr})^2] + \sum_{\substack{k=1\\k\neq j}}^{m-n-1} [g\Delta d^{rkr}\, t^{rkr}\, t^{rjr}] \tag{17}$$

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 coefficient related to trade flows towards r will equal:

$$\Delta t^{snr} = \sum_{k=1}^{m-n} g\Delta d^{rkr} \ t^{snr} \ t^{rkr} \tag{18}$$

(b) Long-term changes

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

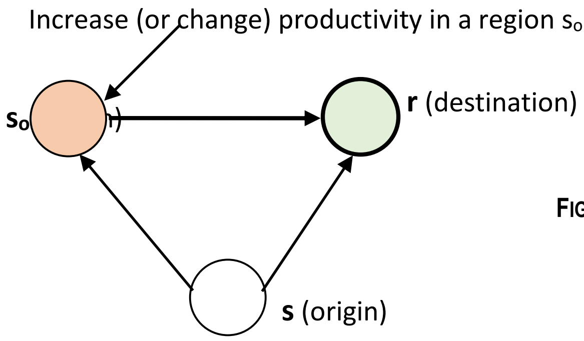

FIGURE 3 - INCREASE (OR CHANGE) PRODUCTIVITY IN A REGION S_O

- The change Δt_i^{sr} of trade coefficient related to trade flows from region s to region r, due to changes in productivity Δp_i^{so}, is estimated by taking the partial differential (where m=3):

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

$$\frac{[-(E_i^s)^c (p_i^s)^e (M^r)^h \exp(-gd^{sr})][e(E_i^{so})^c (p_i^{so})^{e-1} (M^r)^h (\exp(-gd^{sor})]}{\sum_{s=1}^{m} [(E_i^s)^c (p_i^s)^e (M^r)^h \exp(-gd^{sr})]^2} \Delta p_i^{so}$$

$$\Delta t_i^{sr} = -e(\frac{\Delta p_i^{so}}{p_i^{so}}) t_i^{sr} t_i^{sor} \tag{19}$$

- The change Δt_i^{sor} of the trade coefficient related to trade flows from a region s_o to region r, due to changes in productivity Δp_i^{so}, is estimated by taking the partial differential:

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

$$\{[e(E_i^{so})^c(p_i^s)^{e-1}(M^r)^h\exp(-gd^{sor})][\sum_{s=1}^{m}[(E_i^{so})^c(p_i^{so})^e(M^r)^h(\exp(-gd^{sr})]-$$
$$[(E_i^{so})^c(p_i^{so})^e(M^r)^h\exp(-gd^{sor})][c(E_i^{so})^c(p_i^{so})^e(M^r)^h\exp(gd^{sor})]\}\Delta p^{so}/$$
$$\sum_{s=1}^{m}[(E_i^s)^c(p_i^s)^e(M^r)^h\exp(-gd^{sr})]^2$$

$$\Delta t_i^{sor}=e\left(\frac{\Delta p_i^{sor}}{p_i^{so}}\right)[t_i^{sor}-(t_i^{sor})^2] \quad (20)$$

As discussed above, given a known as well as stable demand for a 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 a 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.

Generalizing the above and assuming 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 the productivity of the remaining regions (indirect effect). The overall 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 changes its trade flows toward *r*, as a result of changes in the 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 the productivity of a random region r_j belonging in the group of the regions whose productivity changes (*j*=1,....,k) will be examined. Bearing in mind what was mentioned before about changes in productivity, we will have the following cases:

(a) The direct change of trade coefficients related to trade flows of region r_j to the region r due to the change in productivity p_i^{rj}, comes from equation (20) and equals:

$$\Delta t_i^{rjr}=e\left(\frac{\Delta p_i^{rj}}{p_i^{rj}}\right)[t_i^{rjr}-(t_i^{rjr})^2]>0 \quad (21)$$

(b) The total indirect changes of trade coefficients related to trade flows from region r_k (k≠j) to the region *r*, due to changes in productivity p^{irjr} is equal to:

$$\sum_{\substack{k=1\\k\neq j}}^{m-n} \Delta t^{rkr} = \sum_{\substack{k=1\\k\neq j}}^{m-n-1} [-e(\frac{\Delta p_i^{rj}}{p_i^{rj}}) t_i^{rkr} t_i^{rjr}] < 0 \qquad (22)$$

(c) The total indirect changes of trade coefficients related to trade flows from region s_n to region r, due to changes in productivity p^{irjr}, is equal to:

$$\sum_{n=1}^{m-k} \Delta t^{snr} = \sum_{n=1}^{m-k} [-e(\frac{\Delta p_i^{rj}}{p_i^{rj}})\ t_i^{snr} t_i^{rjr}] < 0 \qquad (23)$$

The change of trade coefficients related to trade flows for each region r_j, (region r_j belongs to the group of regions whose productivity has changed), results from equations (21) and (22) and is equal to:

$$\Delta t_i^{rjr} = e(\frac{\Delta p_i^{rj}}{p_i^{rj}})[\ t_i^{rjr} - (\ t_i^{rjr})^2] + \sum_{\substack{k=1\\k\neq j}}^{m-n-1} [-e(\frac{\Delta p_i^{rkr}}{p_i^{rkr}}) t_i^{rjr} t_i^{rkr}] \qquad (24)$$

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

$$\Delta t^{snr} = \sum_{k=1}^{m-n} [-e(\frac{\Delta p_i^{rk}}{p_i^{rk}})\ t_i^{snr} t_i^{rkr}] \qquad (25)$$

3.4. *Change in final demand due to a decrease in transport costs and the price of goods*

Assuming that the transportation cost savings are not retained by the transportation sector, but are transferred entirely to the region of destination of the goods, the change in final demand will be given by the equation:

$$\Delta Y_i^r = \sum_{s=1}^{m} \sum_{i=1}^{n} (\ t_i^{rs} c_i^{sr} Y_i^r - t_i^{/rs} c_i^{sr} Y_i^r) \qquad (26)$$

Where: ΔY_i^r is the transportation cost savings for region r and Y_i^r is the total transfers (demands) of region r for product i.

3.5. *Change in technological coefficients*

As mentioned above, the basic assumption adopted in the present methodology is that variable only the technological coefficients of the transport sector, as defined in the input-output methodology, are considered. Other methodologies have focused mainly on the calculation of changes in all technological coefficients, underestimating the other effects caused by interregional transport infrastructures (Liew and

Liew, 1984; Liew and Liew, 1985; Sasaki et al., 1987). We consider it particularly difficult for a change in transport costs between certain regions to cause generalized changes in technological coefficients since these changes presuppose the induction of substitution phenomena in the production process of businesses and production units.

Assuming that for the production of a unit quantity of the productive sector j in the region r are required x_{ij}^{r} the input from sector i and x_{Tj}^{r} the input from the transportation sector (Miller and Blair, 2009), c_i^{sr} is the transportation cost required to move input x_{ij}^{r} from region *s* to *r*, w_i the physical weight of the quantity corresponding to a monetary unit of the product of sector *i*, the X_j^r quantity of sector *j* of region *r* which is produced by the above inputs. The input from the transport sector will be calculated from the relationship:

$$x_{Tj}^{r} = \sum_{s=1}^{m}\sum_{i=1}^{n} w_i x_{ij}^{r} t_i^{sr} c_i^{sr} \tag{27}$$

The change of distances between regions *s* and *r* leads to the change of transport costs in sector *i* by Δc_i^{sr} and trade coefficients by Δt_i^{sr}, so that:

$$\Delta c_i^{sr} = c_i^{/sr} - c_i^{sr} \quad \textit{and} \quad \Delta t_i^{sr} = t_i^{/sr} - t_i^{sr} \tag{28}$$

The change in the value of the input from the transport sector will be equal to:

$$\Delta x_{Tj}^{r} = x_{Tj}^{/r} - x_{Tj}^{r} = \sum_{s=1}^{m}\sum_{i=1}^{n} w_i x_{ij}^{r} t_i^{/sr} c_i^{/sr} - \sum_{s=1}^{m}\sum_{i=1}^{n} w_i x_{ij}^{r} t_i^{sr} c_i^{sr} \tag{29}$$

Equation (29) using equations (28) can be written:

$$\Delta x_{Tj}^{r} = x_{Tj}^{/r} - x_{Tj}^{r} = \sum_{s=1}^{m}\sum_{i=1}^{n} w_i x_{ij}^{r} (t_i^{/sr} c_i^{/sr} - t_i^{sr} c_i^{sr})$$

$$\Delta x_{Tj}^{r} = \sum_{s=1}^{m}\sum_{i=1}^{n} w_i x_{ij}^{r} (t_i^{/sr} \Delta c_i^{sr} + t_i^{/sr} c_i^{sr} - t_i^{sr} c_i^{sr})$$

$$\Delta x_{Tj}^{r} = \sum_{s=1}^{m}\sum_{i=1}^{n} w_i x_{ij}^{r} (t_i^{/sr} \Delta c_i^{sr} + c_i^{sr} \Delta t_i^{sr}) \tag{30}$$

According to the definition of technological coefficients (Miller and Blair, 2009), the technological coefficient for the transport sector will be equal to:

$$a_{Tj}^{/r} = \frac{x_{Tj}^{/r}}{X_j^r} = \frac{(x_{Tj}^r + \Delta x_{Tj}^r)}{X_j^r} = a_{Tj}^r + \sum_{s=1}^{m}\sum_{i=1}^{n} a_{ij}^r (t_i^{/sr} \Delta c_i^{sr} - c_i^{sr} \Delta t_i^{sr})$$

$$\Delta\alpha_{Tj}^r = \sum_{s=1}^{m}\sum_{i=1}^{n} w_i \alpha_{ij}^r (t_i^{/sr} \Delta c_i^{sr} + c_i^{sr} \Delta t_i^{sr}) \tag{31}$$

Using equation (31), the change in the technological coefficients of the transport sector is calculated as a function of the terms: w_i, α_{ij}^r, t_i^{sr}, Δc_i^{sr}, c_i^{sr} and Δt_i^{sr}.

3.6. *Changes in accessibility and population potential*

Accessibility of a given location or region is an important topic in urban and regional research connected with transport infrastructures or facilities (O'Kelly and Horner, 2003; Chi, 2012). The definitions used for accessibility vary and are related to the scientific field in which it is used. It is a term often used in transport and spatial planning and is generally understood to mean roughly "ease of access". Similar to accessibility terms are the economic or population or market potential that can be thought of as the nearness of a given place or region to the population or economic activities of the entire regional system. High values in the accessibility or economic potential of a region are associated with developmental advantages since its businesses can transport their products to large populations or economic concentrations with low transportation costs (Stepniak and Rosik, 2018).

The construction and operation of transport infrastructure lead to an increase in the accessibility or economic potential of an area and an improvement in the level of accessibility is associated with an increase in productivity and economic development. Increasing accessibility is understood as the possibility of opportunities for interaction of the people and businesses of an area and the increase of the reach of businesses to make available their products. In other words, improving accessibility is a means to evaluate the impacts of infrastructure investment and related transport policies on regional development.

Accessibility is the measure of the capacity of a location or a region to be reached from or to be reached by, different locations or regions' facilities (O'Kelly and Horner, 2003; Chi, 2012). The use of the terms "accessibility" and "economic or population potential" in regional development studies presuppose their measurement. The problem of measuring the accessibility of a given location is to determine the magnitude of opportunity within some specified distance or threshold of the location. The key variables used to measure the above terms are the population or the size of the economic activity of each region and the interregional distances.

The definition of accessibility is built on the assumption that the attractiveness of a destination increases as the distance, travel time or cost between origin and destination decreases. Thus, the quantitative expression of "accessibility" or "population potential" A_r of the region r in a regional system with n regions can be done by the equation:

$$A_r = \sum_{r \neq s, s=1}^{n-1} P_s d_{rs}^{-1} \tag{32}$$

Where: P_s is the population of region s and d_{rs} is the distance between the regions r and s centroids. It is noted that in many studies, instead of regional population P_s, the total regional product or size of the regional market is used.

Another equation that can be used instead of Eq (32) is:

$$A_r = \sum_{r \neq s, s=1}^{n-1} P_s \exp(-bd_{rs}) \tag{33}$$

Additionally, if the value of A_r is enlarged by a so-called "self-potential", namely the potential produced by the unit itself, the next equation is obtained:

$$A_r = P_i \exp(-bd_{ii}) + \sum_{r \neq s, s=1}^{n-1} P_s \exp(-bd_{rs}) \tag{34}$$

3.7. Changes in businesses' location

In most of the traditional location decision theoretical approaches, distance or transportation cost plays a decisive role in the whole process of locating a firm. However, the actual influence of distance has become increasingly enigmatic nowadays. While the theoretical endeavor of industrial location processes can be traced back to the establishment of industrialization, the theoretical schemata have often their limitations in unraveling practical location decision problems. Much of the contemporary research on industrial location suggests that the actual spatial distribution of firms does not always follow the prevailing theoretical approaches. There are often significant differences between expected and observed industrial patterns. In some respects, this is because most of the existing industrial location theories provide an understanding of only a portion of the empirical world.

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Statistical models can be used to calculate the influence of determinant factors in shaping the size of regional attractiveness for business or economic activities in a general establishment. Among these factors, accessibility plays an important role in the process of businesses' choices of location, since it affects the size of their market by making the distribution of their products more efficient in terms of capacity, cost, and time. This is the main reason why all the relevant theories consider the transport cost as the main factor of business location or location of economic activities choice. These considerations are at the core of classic industrial location theories where transport-dependent activities seek to minimize total transport costs (Spiekermann and Wegener, 2006; Polyzos et al., 2015).

To calculate the spatial "attractiveness" AT_r of each region r, the following general multiple regression equation can be used. In this model, the X_i factors participate, which have been estimated as well as empirical studies have shown, to influence the "spatial behavior" of entrepreneurs:

$$AT_r = a_o + \sum_{i=1}^{n} a_i X_i + e_i \,, \quad e_i \sim N(0, s^2) \tag{35}$$

Another nonlinear statistical or spatial interaction model that can be used is the following:

$$AT_r = a_o \left(\prod_{i=1}^{n} a_i X_i\right) e_i \,, \quad e_i \sim N(0, s^2) \tag{36}$$

The above general equations can be specified using for each region r as a dependent variable the total employment created by the investments (or the value of the investments), As independent variables can be used the accessibility or economic potential of each region (A_r), the natural resources, the existence of an Industrial Area, the government policy and investment incentives, the level of existing infrastructure, the productive dynamism, population characteristics or social capital, the prosperity level and the agglomeration economies. The independent variables can be differentiated or enriched according to the characteristics of the country where the proposed methodology is applied or the economic sector. In addition to the above models, other statistical models can be applied, as they are Binomial Logistic Regression, Multinomial Logistic Regression, and Tobit Analysis.

The interregional distances are included in the calculation of accessibility or economic potential and therefore any change in it, as a result of the construction and operation of interregional infrastructures, changes accordingly the "spatial attractiveness" of each region. The redistribution of economic activities will result in a change in the demand vector, as depicted in the I-O methodology in terms of consumption and investment. The change in the value of an investment for each region will be equal to the following partial differential:

$$\Delta(AT_r) = \frac{\partial(AT)_r}{\partial(A_r)} \Delta(A_r) \tag{37}$$

Regarding the change in consumption, this can be derived by first calculating the change in employment, assuming a linear relationship between investment and employment, and then using private consumption per capita. It is considered understandable that the best representation of reality through the indicators or the way of quantifying the quantities in which each variable is represented will determine, as in any statistical model, the "quality" of the results, which will result from the assessment of the proposed statistical models.

3.8. Changes in enterprises' location that serve transport infrastructure users

Investigating the type of enterprises that serve the transport infrastructure, these are connected mainly with highways and secondarily with airports and ports. These enterprises would be classified into two basic categories (Polyzos et al., 2008):

(a) Enterprises that serve the highways, the ports, and the airports, as well as the needs of people, drivers, and vehicles that move through them;

(b) Enterprises that do not relate in any way to the function of the transport infrastructure or the needs that result from it.

The first category of enterprises has an immediate relationship to the transport infrastructure construction itself, the traffic through it, and its general features. These enterprises relate and depend on the infrastructure and their establishment nearby is based on servicing the needs and demands of anyone moving along it. Consequently, their viability depends on the quantity or needs of the traffic.

In the second category, enterprises that do not relate to the operation of the infrastructure just benefit from the right choice of establishment in interregional areas for two basic reasons: Firstly, they secure their general accessibility due to the proximity of the infrastructure, and thus their easier access to and from the urban centers that usually function as provision centers and consumption centers for the products of the enterprises. Secondly, the establishment of enterprises in interregional areas is considered an advantage for their general “image”. Their location serves their exposure since it is reinforced by everyday visual contact by users of the infrastructure.

The estimation of the transport infrastructures' attractiveness for the location of the enterprises in question can be done using models similar to those described by equations (34) and (35). The independent variables that can be used in this case are (Polyzos et al., 2008): The transport traffic served by the infrastructure, the total population of the region to which the infrastructure belongs, the number of trucks and vehicles of each region, the number of private cars of each region and the level of prosperity of each region.

3.9. Changes in tourism flows

The methodologies that have primarily been developed for the quantitative analysis of tourist attractiveness or the tourist flows to each region can be classified into two basic categories: (a) the linear equation models or multiple regression and (b) the spatial interaction models that mainly presented in the form of gravity models (Polyzos and Arabatzis, 2008). The equation used is as follows: $T_r=f(F_1, F_2, .., F_n)$, where T_r is the number of visitors to region *r* and $F_1, F_2, .., F_n$ are the determinant factors that create or attract tourist flows to *r* and are related to more general characteristics of region *r*, which influences total tourist flows toward it. It is noted that interregional distances or accessibility are included in the determinant factors.

The general form of the models of the first category is as follows:

$$T_r = a_o + \sum_{i=1}^{n} a_i F_i + e_i \tag{38}$$

Another category of models has the next general form:

$$T_{sr} = kP_s^a A_r^b \exp(-cd_{sr}) e_i \tag{39}$$

Where: T_{sr} is the tourist flows from region *s* (origin) to region *r* (destination), P_s^a is the regional factor (or factors) which produces tourist flows (e.g. prosperity level, population, etc.), A_r^b is the indicator of total “attractiveness” of region *r*, d_{sr} is the distance between *s* and *r*, *k* is the geographic constant, *a*, *b*, and *c* are parameters that show the elasticity of tourist flows concerning the other variables.

The change in the tourist flows to each tourist region will be equal to the following partial differential:

$$\Delta(T_{sr}) = \frac{\partial(T_{sr})}{\partial(d_{sr})} \Delta(d_{sr}) \tag{40}$$

3.10. Changes in regional total gross output

All the above derivative or distributive changes bring about the corresponding change in the final demand for investment or consumption of each region, as the final demand defined in the I-O methodology (Miller and Blair, 2009). Using the general equation of the multi-regional input-output model: $X=(I-TA)^{-1}TY$ we calculate the total differential of the equation in terms of the variables T, A, and Y. We will finally have a total change in the total gross output throughout the economy equal to:

$$\Delta X = \frac{\partial X}{\partial T}\Delta T + \frac{\partial X}{\partial A}\Delta A + \frac{\partial X}{\partial Y}\Delta Y \tag{41}$$

- The first term of the right-hand side of the equation (41) will be equal to:

$$\frac{\partial X}{\partial T}\Delta T = \left((I-TA)^{-1}\left[AX+IY\right]\right)\Delta T \tag{42}$$

- The second term of the right-hand side of the equation (41) will be equal to:

$$\frac{\partial X}{\partial A}\Delta A = \left((I-TA)^{-1}\,TX\right)\Delta A \tag{43}$$

- The third term of the right-hand side of the equation (41) will be equal to:

$$\frac{\partial X}{\partial A}\Delta Y = (I-TA)^{-1}T\Delta Y \tag{44}$$

By adding the above three terms we obtain equation (41) in a more detailed form:

$$\Delta X = [(I-TA)^{-1}(AX+IY)]\Delta T + [(I-TA)^{-1}TX]\Delta A + (I-TA)^{-1}T\Delta Y \tag{45}$$

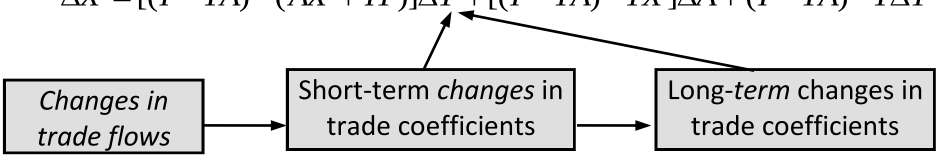
The change in the total gross output for the individual region s, traded with each region r, will be equal to:

$$\Delta X^{s} = (I-TA)^{-1}\sum_{r=1}^{m}[(A^{r}X^{r}+Y^{r})\Delta T^{sr} + T^{sr}X^{r}\Delta A^{r} + T^{sr}\Delta Y^{r}] \tag{46}$$

Next, we will schematically show the estimation of the total changes using equation (41) for all regions or equation (42) for each region separately. In particular, we will show the introduction of all exogenously calculated spatial changes in these equations to determine the changes in the total gross output for the individual region s of each country.

(a) Change in trade coefficients

$$\Delta X = [(I-TA)^{-1}(AX+IY)]\Delta T + [(I-TA)^{-1}TX]\Delta A + (I-TA)^{-1}T\Delta Y \tag{47}$$



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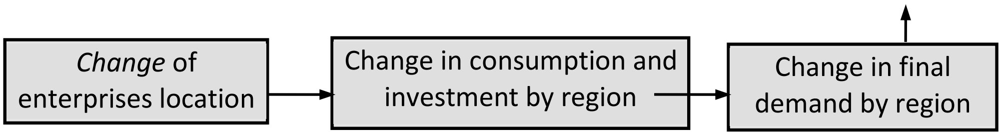
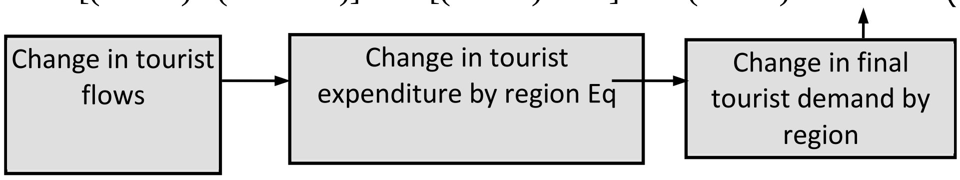
(b) Change of enterprises location

$$\Delta X = [(I - TA)^{-1}(AX + IY)]\Delta T + [(I - TA)^{-1}TX]\Delta A + (I - TA)^{-1}T\Delta Y \tag{48}$$



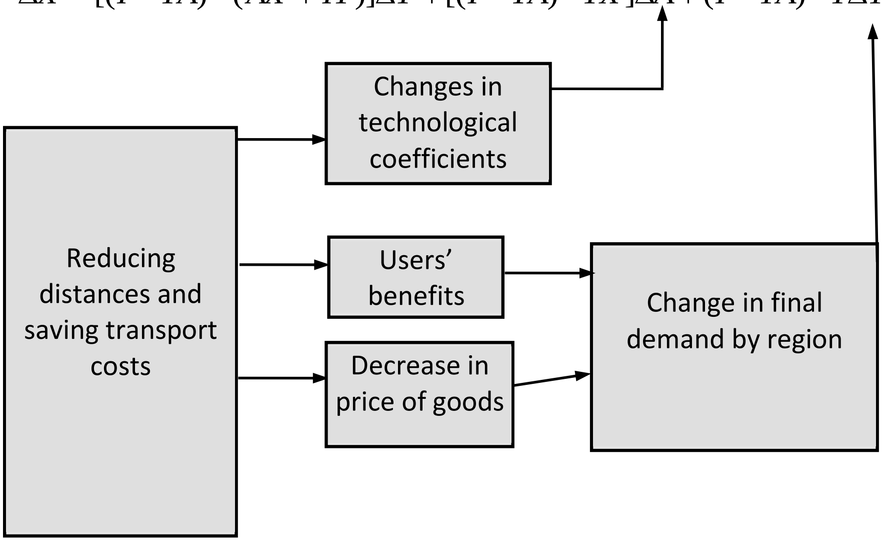
(c) Change in tourist flows

$$\Delta X = [(I - TA)^{-1}(AX + IY)]\Delta T + [(I - TA)^{-1}TX]\Delta A + (I - TA)^{-1}T\Delta Y \tag{49}$$



(d) Savings in transport costs

$$\Delta X = [(I - TA)^{-1}(AX + IY)]\Delta T + [(I - TA)^{-1}TX]\Delta A + (I - TA)^{-1}T\Delta Y \tag{50}$$



If we are interested in counts of jobs, in physical terms, it is possible to estimate relationships between the value of the output of a sector and employment. Therefore, we can estimate the impact of changes in gross output on regional employment (Miller and Blair, 2009). Changes in employment will have a long-term effect on the population sizes of each region and the need for new transport infrastructure, as shown in Figure 1.

4. CONCLUSIONS

In this paper an ex-ante methodology for calculating the economic impacts on the regions, which will occur after the construction and operation of interregional transport projects was proposed, as well as its basic equations were briefly given. The proposed model is developed in general terms, while there is the possibility to modify the intermediate equations, without changing the general framework, depending on the statistical data availability. For instance, there is a possibility to use spatial interdependence models or exponential models instead of the used linear ones. It is also pointed out that the application of the model requires the corresponding quantification of certain variables (e.g. government policy) that are used in the methodology, as well as the calibration of the models by using real statistical data to calculate the included parameters. Overall, this paper provides insights into the quantitative assessment of the spatial-economic changes causes to a regional economy due to the transportation infrastructures' construction, providing a decision-making tool for transport policy and planning, for promoting economic growth, and towards serving regional inequalities' convergence.

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