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Ανταγωνισμός Δημοσίων Δαπανών στον Τομέα των Μεταφορών στην Ελλάδα: Διακλαδικές και Χωρικές Διαστάσεις

Θεόδωρος Τσέκερης

ΠΕΡΙΛΗΨΗ

Τα δίκτυα μεταφορών αποτελούν έναν από τους σημαντικότερους συντελεστές υποδομής που επηρεάζουν την παραγωγή και περιφερειακή οικονομική ανάπτυξη. Συνεπώς, υπάρχουν συνεχείς πιέσεις για επενδύσεις στον τομέα των μεταφορών. Στην Ελλάδα, η ανάπτυξη των δικτύων μεταφορών βασίζεται κυρίως στο Πρόγραμμα Δημοσίων Επενδύσεων, μέσω του οποίου διοχετεύονται κρατικές δαπάνες για μελέτη, κατασκευή, λειτουργία και συντήρηση/επισκευή συγκοινωνιακών έργων. Τα έργα αυτά διαχωρίζονται στις εξής κατηγορίες: (α) οδοί (συμπεριλαμβανομένων των γεφυρών), (β) σιδηρόδρομοι, (γ) αεροδρόμια και πολιτική αεροπορία, (δ) λιμένες και ναυτιλία, και (ε) αστικές δημόσιες συγκοινωνίες. Η παρούσα εργασία στοχεύει στη διερεύνηση των σχέσεων υποκατάστασης (ανταγωνισμού) και συμπληρωματικότητας των δημοσιοεπενδυτικών δαπανών για τις παραπάνω κατηγορίες (κλάδους).

Η μεθοδολογική προσέγγιση βασίζεται σε ένα χωρικό-οικονομικό πρότυπο περιφερειακού ανταγωνισμού, μέσω του οποίου αναπτύσσεται ένα σύστημα διακλαδικών (ανά κατηγορία επένδυσης) εξισώσεων. Το σύστημα αυτό χρησιμοποιεί χρονοσειρές διαστρωματικών στοιχείων (panel), τα οποία αντιστοιχούν σε δημοσιοεπενδυτικές δαπάνες σε κάθε Νομό καθώς και σε διαπεριφερειακά έργα, κατά τη διάρκεια της περιόδου 2000-2007. Οι ελαστικότητες που προκύπτουν από τις επιμέρους εξισώσεις επιτρέπουν τον προσδιορισμό του επιπέδου του ανταγωνισμού ή των συνεργιών (θετικών εξωτερικοτήτων) μεταξύ των δαπανών σε διαφορετικές κατηγορίες του τομέα των μεταφορών στο επίπεδο όλης της χώρας.

Τα αποτελέσματα τονίζουν τη σημασία της προσφοράς του κατάλληλου τύπου συγκοινωνιακής υποδομής ανά περιφέρεια, έτσι ώστε να επιτευχθούν οι ευρωπαϊκοί και εθνικοί στόχοι της πολιτικής των μεταφορών για ενίσχυση της εδαφικής συνοχής και προώθηση της συνδυασμένης χρήσης των μέσων μεταφοράς. Πιο συγκεκριμένα, οι τοπικές επενδύσεις σε μη-οδικές υποδομές καθώς και επενδύσεις σε έργα μεγάλης κλίμακας, διαπεριφερειακού χαρακτήρα μπορούν να παράγουν θετικές χωρικές εξωτερικότητες (spillovers) και να υποστηρίξουν τους προαναφερθέντες στόχους. Οι

ελαστικότητες δείχνουν τη σημαντική εξάρτηση από το παρελθόν της ποσότητας των δημοσιοεπενδυτικών δαπανών σε κάθε κατηγορία, και τις σημαντικές σχέσεις ανταγωνισμού μεταξύ των δαπανών σε οδικά έργα και στα υπόλοιπα συγκοινωνιακά έργα.

Από την άλλη πλευρά, οι περισσότερες δημοσιοεπενδυτικές δαπάνες σε μη-οδικά έργα (σιδηρόδρομους, αεροδρόμια, λιμένες και αστικές δημόσιες συγκοινωνίες) είναι συμπληρωματικές και συμμετρικές - ως προς την κατεύθυνση των επιδράσεων - μεταξύ τους. Ιδιαίτερα, οι δαπάνες για αεροδρόμια έχουν τις πλέον σημαντικές θετικές αλληλεπιδράσεις με τις δαπάνες για άλλες υποδομές δημόσιων μεταφορών. Οι θετικές αλληλεπιδράσεις μεταξύ των δημοσιοεπενδυτικών δαπανών για αεροδρόμια και λιμένες υπογραμμίζουν την ανάγκη συνδυασμένης ανάπτυξης αυτών των μέσων για την αποτελεσματική εξυπηρέτηση των περιοχών της περιφέρειας, ιδιαίτερα των νήσων.

Οι αρνητικές επιδράσεις μεταξύ δημοσιοεπενδυτικών δαπανών για υποδομές δημόσιων μεταφορών μπορούν να αποδοθούν στην ύπαρξη γεωγραφικών και θεσμικών περιορισμών που διέπουν τη λειτουργία των συστημάτων μεταφορών. Αναλυτικότερα, δείχνουν την ανάγκη βελτίωσης της διασυνδεσιμότητας και διαλειτουργικότητας μεταξύ λιμένων και σιδηροδρόμων στην ενδοχώρα, και ενίσχυσης των αδύναμων σχέσεων μεταξύ αστικών δημόσιων συγκοινωνιών και λοιπών δημόσιων (σιδηροδρομικών, θαλάσσιων, αεροπορικών) μεταφορών. Συμπερασματικά, ο καθορισμός των διακλαδικών δημοσιονομικών εξωτερικοτήτων στον τομέα των μεταφορών πρέπει να αποτελεί αναπόσπαστο στοιχείο του στρατηγικού σχεδιασμού και αξιολόγησης των επενδυτικών προγραμμάτων των συγκοινωνιακών υποδομών.

ABSTRACT

The development of transport networks requires significant public expenditures in several types of (road, rail, port, airport and urban public transport) infrastructure and services. This paper aims at examining substitution and complementarity relationships between public expenditures in different types of investment in the Greek transport sector. Based on a spatio-economic model of regional competition, a system of panel regression equations is developed to examine the country-wide patterns of inter-modal expenditure competition with the use of data at the NUTS III-level of Prefecture. In this study, the data refer to the Public Investment Program of the Greek government for the transport sector during the period 2000-2007. The results indicate the statistically significant scale effects of transport investments as well as the statistically significant substitution effects of road infrastructure on other types of transport investment. On the other hand, most public expenditures in non-road (including urban public transport) facilities are found to be complementary to each other. In particular, airport expenditure relates to the most significant synergistic effects on expenditures in other types of public transport facilities. Policy-makers need to consider these expenditure externalities in the transport sector for the strategic planning and evaluation of infrastructure supply, and coordinate or subsidize public transport projects with significant positive externalities.

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1. Introduction

Transport investments are traditionally deemed to bear a significant role in the urban, regional and national economic growth. The enhancement of regional accessibility induced by such investments can support policy objectives on the promotion of territorial cohesion and social equity. At the same time, investments which can increase the (combined) use of public transport modes are encouraged to support the objectives of energy-efficient and environmentally sustainable mobility (see CEC, 2001; CEC, 2006). The development of regional transport networks typically relies on public investments, in terms of government expenditure, on several types of (road, rail, port, airport and urban public transport) infrastructure, including their operational and maintenance services. Each type of infrastructure can operate independently, but only to a certain extent, due to geographical constraints and the need for transshipment of freight and interchange of passenger journeys to reduce transport costs and increase the level of service.

More specifically, transport infrastructures can be either complementary, when they operate in synergy between (or complement with) each other, or competitive, when they compete with each other in their use. Correspondingly, the investments on two different types of transport infrastructure can be regarded as either competitive (or substitutive) or complementary, according to whether the expenditures for them move in the opposite or the same direction. In addition to the inter-modal competition among government expenditures for different types of transport investment, another form of competition relates to the spatial interaction of transport investments allocated to different regional units. Namely, transport investments made on two different regions can be regarded as either competitive or complementary, according to whether the expenditures for them moves in the opposite or the same direction.

The *inter-modal* and *spatial* substitution or complementarity relationship among the government transport expenditures can be influenced by a range of factors. Such factors may include regulation, geographical and access conditions, operational and technological characteristics of each type of infrastructure, social and economic development needs, financial and regional policy requirements, and political criteria. In turn, the inter-modal and spatial competition between transport expenditures can have a significant social, economic and spatial impact on the regional development pattern and the future allocation of public investments. The above linkages underline the endogenous dynamic nature of government policy on transport investment. De Mello (2002), Lambrinidis et al. (2005) and Kemmerling and Stephan (2008) provided econometric analyses of the factors influencing public investment decisions on (transport) infrastructure.

This paper proposes a set of empirical spatio-economic models, which build on the model of Dendrinos and Sonis (1988, 1990), referred to here as DS model, to allow determining different forms of substitution-complementarity relationships between public expenditures in the transport sector. More specifically, three models are developed here:

(i) the classical DS model for the analysis of expenditure competition among regions (at the administrative level of Development Regions - NUTS I) for each type of transport investment,

(ii) a modified DS model for the analysis of expenditure competition among different types of transport investment in each region (at the NUTS I level), and

(iii) a panel-type DS model for the global (country-wide) analysis of expenditure competition among different types of transport investment (based on data at the administrative levels of Regions - NUTS II and Prefectures - NUTS III).

Besides, the level of competition in public expenditures for transport projects of different geographical scale (i.e., region-specific vs. interregional scale) will be taken into consideration. Section 2 analyzes existing research related to the competition in public investment for transport. Section 3 provides the formulation of the empirical models of the study. Section 4 describes the sources and characteristics of the empirical data. Section 5 presents and discusses the findings of the study and Section 6 concludes.

2. Public Investment Competition in the Transport Sector

The investigation of public investment (or expenditure) competition in the transport sector is quite limited in the current literature, although its importance has been recognized in several studies. Starkie (1979) stressed the importance of considering the expenditure competition between road and rail in the development of the British inter-urban transport network. Recently, Bogart (2008) demonstrated for the same area the historical presence of inter-modal network externalities through investing on different types of infrastructure, such as road, canal and port. De Borger and Proost (2004) discussed the fiscal externalities arising when the transport pricing or expenditure policy of one government affects the policy of other governments by producing congestion and environmental externalities. The fiscal externalities resulting from infrastructure investments in a country/region can be either *direct*, such as benefit spillovers to other countries/regions, or *indirect*, e.g., due to attraction of foreign businesses in that country/region.

Dall'erba (2004) applied the DS model using regional data on gross value added in the total transport and communication sector in the Iberian Peninsula to show that (a) the benefits of these investments are higher in the core (Spanish) regions at the expense of peripheral regions of Spain and Portugal, and (b) the importance of examining interregional relationships at the sectoral level. Nonetheless, the investigation of interregional investment competition requires recognition of the different typology of transport projects. Investments on different modes can reduce transport costs through increasing network connectivity and interoperability. But new transport modes may compete with old ones and induce additional costs when they have to be integrated with the existing network and increase the total distance covered (Combes and Linnemer, 2000). For the U.S., Glass (2008) employed a vector error correction (VEC) model to show that public expenditure in transport should not be increased in order to stimulate private investment and/or output. Also, he found causality effects over time from private investment to public spending in waterways and highways, and from spending in highways to government expenditure in aviation. Furthermore, different types of infrastructure can act on different sources of market size and production cost asymmetries and, hence, lead to different spillover effects (see, e.g., Argyris and Kostopoulou, 2000; Banister and Berechman, 2003; Ottaviano, 2008).

A distinction can be made between (i) *local* or *region-specific* infrastructure, which mainly affects short-distance interactions and typically involves linear (axial or radial) infrastructure, like that of local roads and railways, and (ii) *global* or *interregional* infrastructure, which mainly affects long-distance interactions and mainly refers to interregional highway and (high-speed) rail networks. The former type usually alters the *attraction* of economic activity through increasing the public infrastructure capital of the region, whereas the latter type often alters *accessibility* through changing the centrality of the traversed regions in the transport network and the spatial economy (Ottaviano, 2008). Other types of infrastructure, such as those of ports and airports can be related to both region-specific and interregional types of investment. The latter type encompasses major airports which constitute *hubs* of interregional air transport networks, and large ports which are regarded as (national or international) sea *gates* and parts of interregional maritime transport corridors.

Investments on transport infrastructure of different (intraregional vs. interregional) scale interact with each other and influence the spatial economy of the regions. Specifically, a reduction of the interregional transport cost has been found to increase polarization of the space economy, but a reduction of the local transport cost in less developed regions favors a more balanced development (Krugman, 1991; Vickerman et al., 1999; Martin, 2000). On the other hand, it has been argued that improved interregional infrastructure can also support a more even distribution of economic activities when the prices of non-tradables are much lower in less developed regions and when it promotes long-distance commuting (Puga, 1999; Ottaviano, 2008).

Summing up, public expenditures in different categories of the transport sector can significantly affect (either positively or negatively) each other, depending on the infrastructure typology and characteristics of each region. This interaction takes place through changes in the attraction and accessibility of the regions, and the dispersion or agglomeration of their economic activity, inducing the need for supply of new (or better quality) infrastructure. The following Section describes a set of empirical spatio-economic models for representing the various sources of transport expenditure competition mentioned before.

3. Formulation of the models

The present paper suggests and applies an empirical framework which is grounded on a formal model of the strategic interaction process of transport investments of different type among regions. This framework provides an extension of the DS model, which departs from the standard gravity ideas to posit a competition between regions for a share of some national aggregate, involving the consideration of relative dynamics. As such, the DS model has been used to investigate the substitution-complementarity relationships of aggregate, macroeconomic measures, like income, GDP and investment, between regions. A review of relevant models of spatio-economic competition among regions is provided in (Hewings et al., 2004).

The following Subsections provide the corresponding formulations of (i) the interregional expenditure competition model, focusing on the spatial interaction of transport expenditure for a particular mode, in accordance with the original conception of the DS model, (ii) the local inter-modal expenditure competition model, concentrating on the inter-modal interaction of transport expenditure at a specific region, and (iii) the global inter-modal expenditure competition model, dealing with the inter-modal interaction of transport expenditure at the whole country and allowing the use of expenditure data at a significantly finer level of spatial resolution than in the standard practice of the DS model.

3.1 Interregional expenditure competition model

Let x_{mr}^{t} denote the relative public spending, in terms of the total national transport expenditure, of the government in region r for a specific transport infrastructure of type (or mode) m at time t. Also, let assume that there are R regional units (e.g., of NUTS I level) in the whole country. Then, the interregional distribution of the relative transport expenditure allocated to a particular mode m (whose subscript is fixed and omitted below for brevity purposes) can be written as:

$$X^{t} = \left[x_{1}^{t}, \ldots, x_{r}^{t}, \ldots, x_{R}^{t}\right], \quad r = 1, \ldots, R; \quad t = 1, \ldots, T \tag{1}$$

Equation (1) can be seen as a discrete system of spatial distributional dynamics. The discrete time dynamics can be given as:

$$x_{r}^{t+1} = \left[\frac{F_{r}\left(x^{t}\right)}{\sum_{p=1}^{R} F_{p}\left(x^{t}\right)}\right], \quad p, r = 1, \ldots, R; \quad t = 1, \ldots, T \tag{2}$$

where $0 < x_r^t < 1$, $F_r(x^t) > 0$, and $\sum_r x_r^t = 1$. The function $F_r(.)$ denotes the locational and temporal comparative advantages of spending at region r and time t. The measure of $F_r(.)$ for each region r is typically expressed in terms of a numeraire (or reference) region. This numeraire ensures that the shares of all regions sum up to one, implying that the fixed total public spending in the transport sector has to be mutually divided among existing regions. Besides, the numeraire offers a plausible way to represent regional interaction, since the transport investment in a specific region is expressed in terms of the investment in other regions.

Especially, by expressing the dependent variable as the ratio of transport expenditure in a specific region to the transport expenditure in the 'richest' region (with the highest concentration of transport expenditure), a plausible metric of the interregional investment balance, or *spatial equity* of transport expenditure can be obtained. In the current context, this balance (or equity) measure for each region is defined with respect to the Attica Region, where the capital city of Athens is located and which attracts on average the largest absolute share of transport investments in Greece, compared to the other Regions (see Subsection 4.2). The DS modeling framework intrinsically implies a competition relationship between regions (or types of investment, as it will be demonstrated in Subsection 3.2) to obtain the maximum possible share, in accordance with a zero-sum game in which the growth in one region (or investment category) takes place at the expense of, at least, one another.

Assuming that the first region ($r = 1$) is considered as the numeraire, then, the transport expenditure in mode m at some region $r \neq 1$ and time t can be expressed in terms of this numeraire, as follows:

$$G_r(x^t) = \frac{F_r(x^t)}{F_1(x^t)}, \quad \forall\, r = 2, 3, \ldots, R \tag{3}$$

Based on the above transformation, equation (2) results in the following system of equations, depending on whether region r refers to the numeraire region ($r = 1$) or some other region ($r \neq 1$):

$$\begin{cases} x_1^{t+1} = \dfrac{1}{1 + \sum_{r=2}^{R} G_r\left(x^t\right)} \\ x_r^{t+1} = x_1^{t+1}\, G_r\left(x^t\right), \qquad \text{where } r = 2, 3, \ldots, R \end{cases} \tag{4}$$

The function $F_r(.)$ can take any arbitrary form as long as it satisfies the positive value property. This paper assumes a multiplicative specification of $G_r(x)$, as suggested by Dendrinos and Sonis (1988), that is:

$$G_r\left(x^t\right) = A_r \prod_p \left(x_p^t\right)^{a_{rp}}, \qquad \text{where} \quad r = 2, 3, \ldots, R; \quad p = 1, \ldots, R \tag{5}$$

The coefficient $A_r > 0$ denotes the locational advantages of investing at regions $r = 2, 3, \ldots, R$. This multiplicative specification yields the following log-linear equation:

$$\ln x_r^{t+1} - \ln x_1^{t+1} = \ln A_r + \sum_{p=1}^{R} a_{rp} \ln x_p^t, \quad \text{where} \quad r = 2, 3, \ldots, R; \quad p = 1, \ldots, R \tag{6}$$

The coefficient $a_{rp} = \partial \ln G_r\left(x^t\right) / \partial x_p^t$ is an elasticity term which denotes the percentage change of transport expenditure, i.e., the percentage growth in share at region r relative to that at region 1 (the numeraire), with respect to a unit percentage change of transport expenditure at region p. A positive value of a_{rp} indicates complementarity growth in expenditure shares between the two regions, r and p. On the contrary, a negative value of a_{rp} shows a competitive relationship between the two regions, i.e., if the share in one region grows, the share of the other declines. Relationship (6) comprises a system of equations which are linear in parameters. Hence, the Seemingly Unrelated Regressions (SUR) technique can be employed to provide efficient parameter estimates, in accordance with the standard practice of solving the various versions of the DS model.

3.2 Local inter-modal expenditure competition model

The standard DS modeling framework of spatial interaction analysis for a specific sector of the economy can be suitably modified to consider the intra-sectoral interaction of investments at a specific region. Let y_{mr}^{t} denote the relative public spending, in terms of the total transport expenditure for all modes, for transport infrastructure of type (or mode) m at a specific region r and time t. Also, let assume that there are M types of transport investment (or available modes) in that region. Then, the inter-modal distribution of the relative transport expenditure at region r (whose subscript is fixed and omitted below for brevity purposes) can be written as:

$$Y^{t} = \left[y_{1}^{t}, \ldots, y_{m}^{t}, \ldots, y_{M}^{t}\right], \quad m = 1, \ldots, M; \quad t = 1, \ldots, T \tag{7}$$

Equation (7) can be seen as a discrete system of intra-sectoral distributional dynamics. The discrete time dynamics can be given as:

$$y_{m}^{t+1} = \left[\frac{F_{m}\left(y^{t}\right)}{\sum_{k=1}^{M} F_{k}\left(y^{t}\right)}\right], \quad k, m = 1, \ldots, M; \quad t = 1, \ldots, T \tag{8}$$

where $0 < y_{m}^{t} < 1$, $F_{m}\left(y^{t}\right) > 0$, and $\sum_{m} y_{m}^{t} = 1$. The function $F_{m}(.)$ denotes the mode- and time-specific comparative advantages of spending in mode m and time t. The measure of $F_{m}(.)$ for each mode m is expressed in terms of a numeraire (or reference) mode, likewise the regional numeraire in the interregional expenditure competition model. In the current context, this numeraire ensures that the expenditure shares of all modes sum up to one, and represents inter-modal interaction by expressing the investment in a specific mode in terms of the investment in other modes. The expression of the dependent variable as the ratio of non-road transport (including urban public transport) expenditure to road expenditure (i.e., road is the reference mode) can provide here a plausible metric of the inter-modal investment balance, or *inter-modal equity*, in each region. Specifically, this balance (or equity) measure can reflect the ability of transport investment policy to enhance the sustainable regional development objectives, in terms of promoting more environmentally friendly and energy efficient modes of transport.

By making similar assumptions concerning the selection of a numeraire ($m = 1$), the transport expenditure in some mode $m \neq 1$ at region r and time t can be expressed in terms of this numeraire, as follows:

$$G_m\left(y^t\right) = \frac{F_m\left(y^t\right)}{F_1\left(y^t\right)}, \quad \forall\, m = 2, 3, \ldots, M \tag{9}$$

Subsequently, equation (8) yields the following system of equations:

$$\begin{cases} y_1^{t+1} = \dfrac{1}{1 + \sum\limits_{m=2}^{M} G_m\left(y^t\right)} \\ y_m^{t+1} = y_1^{t+1}\, G_m\left(y^t\right), \qquad \text{where } m = 2, 3, \ldots, M \end{cases} \tag{10}$$

By assuming a multiplicative specification of $G_m(y)$, that is:

$$G_m\left(y^t\right) = B_m \prod\nolimits_k \left(y_k^t\right)^{b_{mk}}, \qquad \text{where} \quad m = 2, 3, \ldots, M; \quad k = 1, \ldots, M\ , \tag{11}$$

where the coefficient $B_m > 0$ denotes the advantages associated with the investment type or mode $m = 2, 3, \ldots, M$, the following log-linear equation is obtained:

$$\ln y_m^{t+1} - \ln y_1^{t+1} = \ln B_m + \sum_{k=1}^{M} b_{mk} \ln y_k^t, \quad \text{where} \quad m = 2, 3, \ldots, M; \quad k = 1, \ldots, M \tag{12}$$

The coefficient $b_{mk} = \partial \ln G_m\left(y^t\right) / \partial y_k^t$ is an elasticity term which denotes the percentage change of transport expenditure, i.e., the percentage growth in share of mode m relative to that of mode 1 (the numeraire), with respect to a unit percentage change of transport expenditure in mode k. A positive value of b_{mk} indicates synergistic effect, i.e. complementary growth in expenditure shares between the two modes, m and k. On the contrary, a negative value of b_{mk} shows a competitive relationship in the public expenditure allocation between the two modes. Namely, if the expenditure share of one mode grows, the share of the other declines. As relationship (6), the relationship (12) comprises a system of linear equations which can be resolved with the use of the SUR technique.

3.3 Global inter-modal expenditure competition model

The local inter-modal expenditure competition model can represent the relative complementarity and substitution relationships between investments in alternative modes of transport at a specific regional entity. However, because of the significant limitation in the degrees of freedom which typically arises in the standard (concerning the spatial interaction) as well as the modified (concerning the sectoral interaction) DS modeling framework, the geographical aggregation of the data is usually limited to the NUTS I classification level or involves a set of competitive/complementary NUTS II-level Regions within a specific NUTS I Development Region (e.g., see Dall'erba, 2004; Nazara et al., 2006).

Such a low level of spatial aggregation cannot adequately handle the increased variability in public expenditure for different transport projects at the Prefecture (NUTS III) level and does not allow for corresponding local-specific fixed effects. These effects can be used to represent unobserved heterogeneity and omitted variables which influence the allocation of transport investments among Prefectures. In addition, the consideration of both the time-series and cross-sectional dimensions of the data can increase the precision and consistency of parameter estimates, due to the presence of dynamics and correlated group- and time-specific effects in the problem structure.

For the above reasons, another modeling formulation is developed here which builds on the local inter-modal expenditure competition model, by stacking together cross-sectional and time-series (panel-type) information about the location and time of each type of investment in a system-wide manner. The log-linear panel-type DS model of the global (country-wide) analysis of inter-modal expenditure competition lies on the theoretical basis of the modified DS model, as described in Subsection 3.2, incorporating time- and region-specific fixed effects, as follows:

$$\ln y_{mr}^{t+1} - \ln y_{1r}^{t+1} = \ln B_m + \sum_{k=1}^{M} b_{mkr} \ln y_{kr}^{t} + \eta_{mr} S_r + \theta_m^t L^t + u_m, \qquad m = 2, 3, \ldots, M; \quad k = 1, \ldots, M \tag{13}$$

In the above system of $(M-1)$ fixed-effect panel regression equations, S_r are time-invariant local-specific dummies (column of ones) corresponding to each region (r), and η_{mr} are the corresponding spatial dummy coefficients for each mode m, which account for unobserved or omitted heterogeneity across Prefectures that does not vary over time (e.g., geographical location and morphology, climate and local infrastructure conditions). On the other hand, L^t refers to dummies capturing region-invariant time-specific effects, and θ_m^t are the corresponding time dummy coefficients for each mode m, which are common to all Prefectures but vary across time (for instance, rate of technological change, political and economic fluctuations, and development policies of the central government). The term $u_m \sim N(0, \sigma^2)$ denotes the random disturbances (shocks) of the share growth equation of each type of investment. This term is assumed to be serially uncorrelated and adds stochasticity to the investment distributional dynamics of the transport sector.

The (positive or negative) sign of coefficient b_{mkr} provides information about the (complementarity or substitution) relationship of global (country-wide) expenditure shares of modes m and k . The formulation of the panel-type DS model gives rise to a set of Least-Squares equations with Dummy Variables (LSDV) that leads to asymptotically efficient estimators, unlike Ordinary Least Squares (OLS) which do not guarantee efficient estimates of the system coefficients (Baltagi, 2005). The LSDV approach constitutes a two-way (fixed group and time effects) model, which can appropriately treat the panel effects of the current dataset and provides robust estimates. The estimator which is employed to solve the model refers to the iterative method of SUR.

It is noted that the current panel-type modeling framework does not involve the estimation of spatial spillover effects which are often considered in regional production function models, e.g., through the use of an *a priori* spatial weight matrix. On the contrary, it implicitly recognizes that expenditure externalities may diffuse quite far, even in the case of localized transport projects. Such conditions, where contiguity weight matrices evidently present definitional/accuracy problems, can be found in certain areas, like Greece (see Ioannides and Petrakos, 2000; Prodromidis, 2009) as well as elsewhere (e.g., see De Mello, 2002; Nazara et al., 2006), where several regions are noncontiguous, separated by physical 'borders', such as the Aegean and Ionian Sea and large mountainous blocks in the mainland of Greece.

4. Data Sources and Description

4.1 Data sources

The study uses expenditure data from the Public Investment Program (PIP) of the Greek government, which provides the main channel for public investment in the country, for construction, operations and maintenance in the five categories of the transport sector: (i) roads (including bridges), (ii) railways, (iii) airports and aviation, (iv) seaports and maritime transport and (v) urban public transport. The measure of expenditure, in terms of actual spending Euros, can offer a more precise metric of the level of realized public investments, compared to the apportioned region/state public capital stock data which are typically used in the existing literature (Sloboda and Yao, 2008).

The model employs data spanning the current decade period 2000-2007, for which consistent information on public spending in the transport sector is available from the Greek Ministry of Economy and Finance. The expenditure data have been deflated at 2005 constant prices based on the government expenditure deflator of the National Statistical Service of Greece (NSSG).The study period largely coincides with the third programming period 2000-2007 of the Community Support Framework (CSF) of the European Union, where special attention was given to large-scale (interregional) transport infrastructure projects to enhance regional development, as well as to transport projects necessary for the preparation of the 2004 Summer Olympic Games in Athens. Fig. 1 illustrates the administrative regions of Greece at the Prefecture (NUTS III) level, as well as the Regions (NUTS II) and the Development Regions (NUTS I) in which they are included.

1.Attica	*11.Pieria*	*21.Rhodope*	*31.Chios*	*41.Karditsa*
2.Euboea	*12.Serres*	*22.Xanthi*	*32.Lesvos*	*42.Larissa*
3.Evrytania	*13.Thessaloniki*	*23.Arta*	*33.Samos*	*43.Magnesia*
4.Phocis	*14.Chania*	*24.Ioannina*	*34.Arcadia*	*44.Trikala*
5.Phthiotis	*15.Heraklion*	*25.Preveza*	*35.Argolis*	*45.Achaea*
6.Boeotia	*16.Lasithi*	*26.Thesprotia*	*36.Corinthia*	*46.Aetolia-Acarnania*
7.Chalkidiki	*17.Rethymno*	*27.Corfu*	*37.Laconia*	*47.Elis*
8.Imathia	*18.Drama*	*28.Kefalonia*	*38.Messinia*	*48.Florina*
9.Kilkis	*19.Evros*	*29.Lefkada*	*39.Cyclades*	*49.Grevena*
10.Pella	*20.Kavala*	*30.Zakynthos*	*40.Dodecanese*	*50.Kastoria*
				51.Kozani
				52.a: Mount Athos

Note: NUTS I-1 (North) includes Chalkidiki, Imathia, Kilkis, Pella, Pieria, Serres, Thessaloniki (NUTS II-Central Macedonia), Drama, Evros, Kavala, Rhodope, Xanthi (NUTS II-East Macedonia and Thrace), Karditsa, Larissa, Magnesia, Trikala (NUTS II-Thessaly), Florina, Grevena, Kastoria and Kozani (NUTS II-Western Macedonia). NUTS I-2 (Central) includes Euboea, Evrytania, Phocis, Phthiotis, Boeotia (NUTS II-Central Greece), Arta, Ioannina, Preveza, Thesprotia (NUTS II-Epirus), Corfu, Kefalonia, Lefkada, Zakynthos (NUTS II-Ionian Islands), Arcadia, Argolis, Corinthia, Laconia, Messinia (NUTS II-Peloponnesus), Achaea, Aetolia-Acarnania and Elis (NUTS II-Western Greece). NUTS I-3 includes Attica (also NUTS II- Attica). NUTS I-4 (Aegean) includes Chania, Heraklion, Lasithi, Rethymno (NUTS II-Crete), Chios, Lesvos, Samos (NUTS II-North Aegean), Dodecanese and Cyclades (NUTS II-South Aegean).

Fig. 1 Illustration of the administrative regions (at the NUTS III level of Prefectures) of Greece

4.2 Descriptive analysis of the study data

This Subsection provides an exploratory analysis of the spatial and inter-modal distribution of public expenditure in the transport sector in Greece. Fig. 2 illustrates the inter-temporal evolution of the Greek PIP expenditure shares for different Development Regions (NUTS I) and interregional transport projects in the period 2000-2007. The interregional (mainly road, and rail) transport investments cover on average the largest share (38.4%) of public expenditure in the transport sector in the given period, albeit they present a significantly decreasing trend (-23%). Regarding the region-specific investments, Attica attracts on average the largest share (23%) of total transport expenditure in this period. However, the shares of total transport expenditure allocated to the North and Central Development Regions (on average, 19.1% and 17.1%, respectively) manifest a significant growth, particularly after 2004. The share of total transport expenditure allocated to the Development Region of the Aegean remains low in this period, ranging between 2-3%.

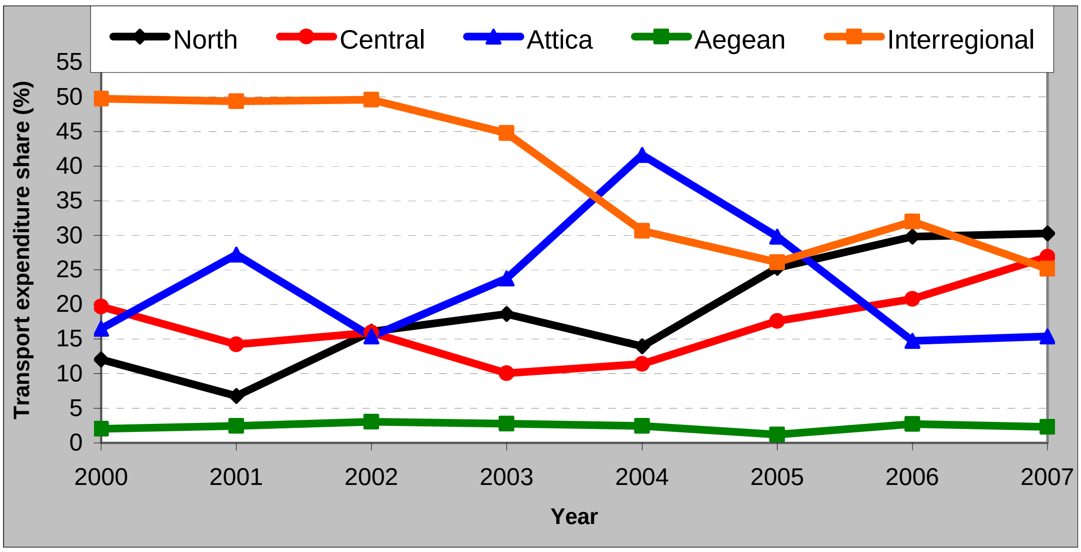

Fig. 2 Inter-temporal evolution of the Greek public expenditure shares in the transport sector for different Development Regions (NUTS I)

Fig. 3 presents the inter-temporal evolution of the Greek PIP expenditure shares for different transport categories in the period 2000-2007. On average, road expenditure covers the 56.3% of the total transport expenditure in the given period, with a significant increase since 2004. The public expenditures in railways (17.6%) and urban public transport (15.7%) follow in sequence, with divergent trends after 2001. Seaport expenditure covers the 6.4% (with increasing trend) and airport expenditure the 4.0% (with decreasing trend) of the total transport expenditure in the given period.

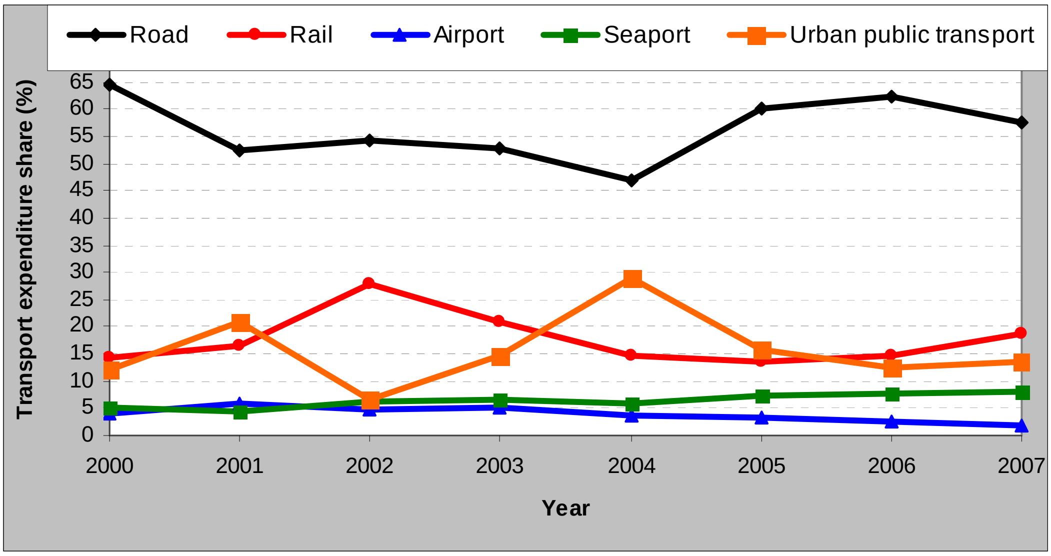

Fig. 3 Inter-temporal evolution of the Greek public expenditure shares in different transport categories

In order to examine the variability of transport expenditures among regions and different types of investment, a dimensionless, normalized measure of the dispersion of a probability distribution, that is the coefficient of variation (C.V.) is used here, which is defined as follows:

$$\text{C.V.} = \frac{\sigma}{\overline{X}}, \qquad (14)$$

where σ is the standard deviation and $\overline{X}$ the mean of transport expenditures (a) in different modes at a specific region (hence, defining a measure of inter-modal dispersion), or, (b) in different regions for a particular mode (hence, defining a measure of spatial or interregional dispersion). Generally speaking, a high degree of inter-modal dispersion and a low degree of interregional dispersion would entail increased inter-modal and spatial balance in the allocation of transport expenditures and a more equitable public investment policy in the transport sector.

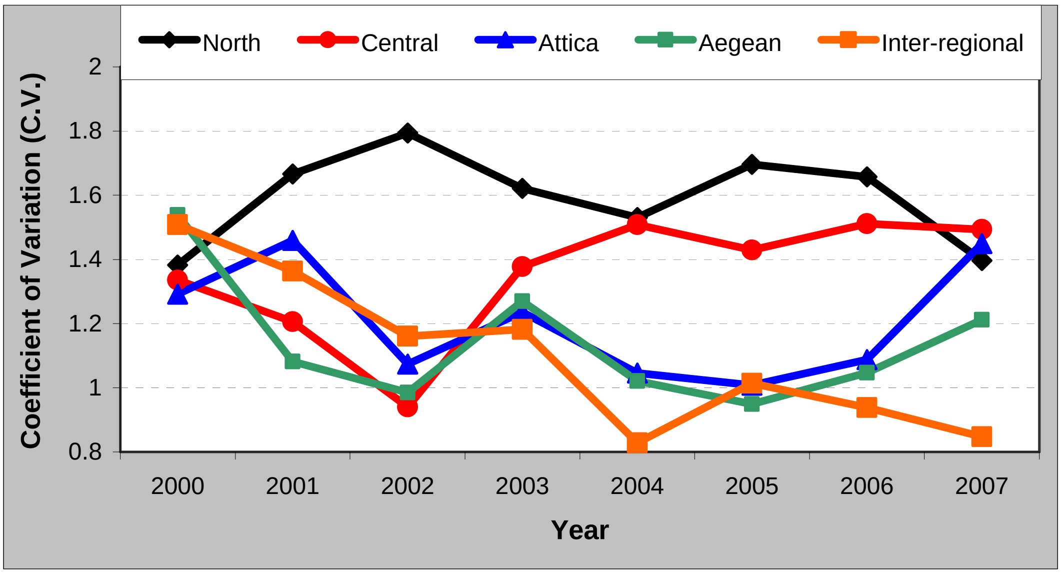

Fig. 4 Inter-modal dispersion of transport expenditures over the Greek Development Regions (NUTS I level)

Fig. 4 indicates that the inter-modal dispersion of transport expenditures manifests considerable inter-temporal fluctuations and takes the largest values, on average, for the North (NUTS I-1) and Central (NUTS I-2) Regions of the country. Namely, the public investments in these Regions are more dispersed over the various transport modes than in the other Regions, which mostly concentrate on urban public transport and railway (in NUTS I-3, Attica), and airport and seaport facilities (in NUTS I-4, Aegean). The interregional investments are the most concentrated ones (mainly on trans-European and national road projects and, at a lesser extent, high-speed rail projects), compared to the transport investments in specific Regions. Therefore, the NUTS I-level Regions of North and Central Greece can be generally considered as more inter-modally balanced than the other Regions, although Attica in 2007 nearly reached the same level of inter-modal dispersion as those Regions.

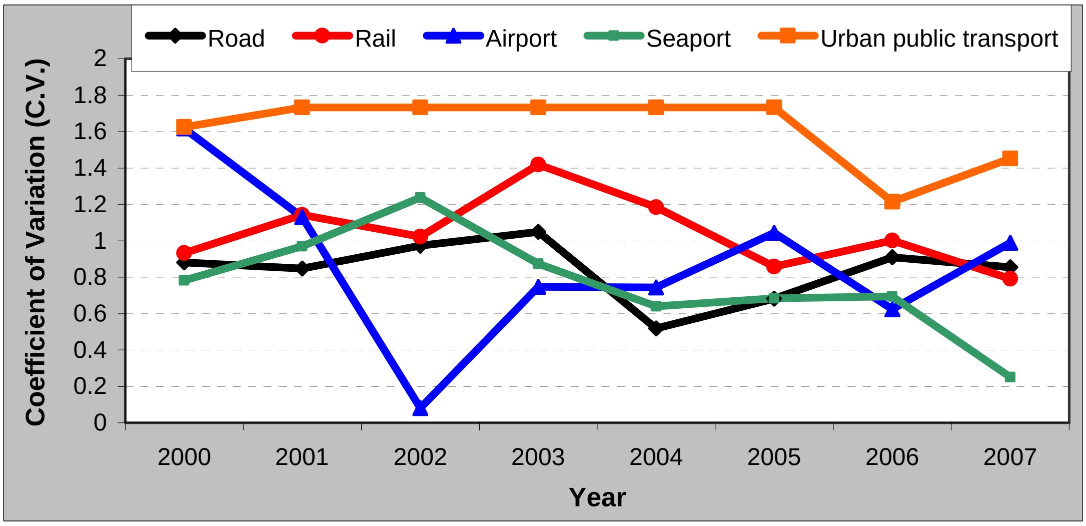

Fig. 5 Spatial dispersion of public expenditure for different types of transport investment in Greece at the NUTS I level

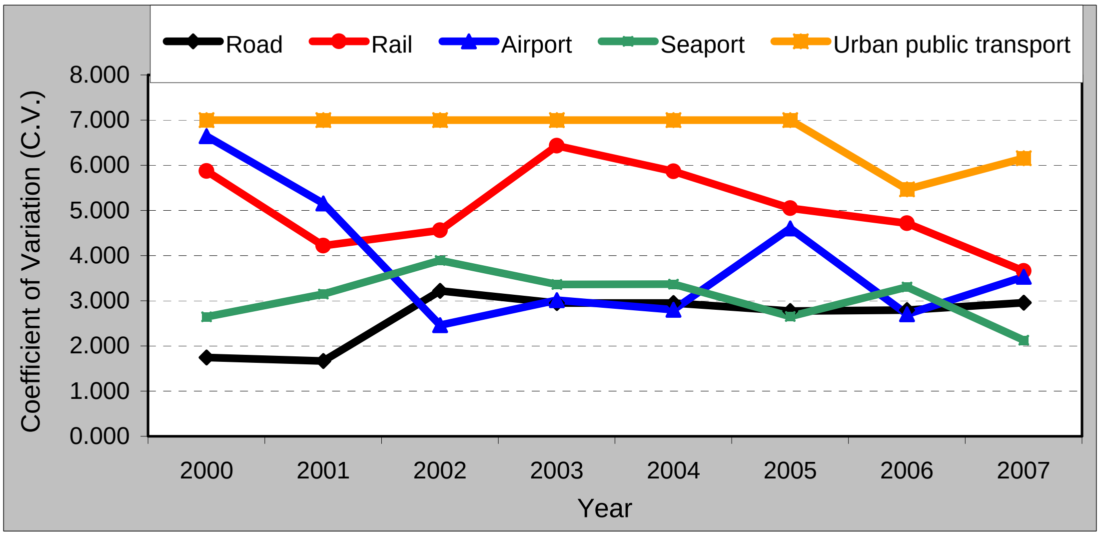

Fig. 6 Spatial dispersion of public expenditure for different types of transport investment in Greece at the NUTS III level

Figs. 5 and 6 show the spatial dispersion of public expenditure in different types of transport investment in Greece at the administrative levels of NUTS I and NUTS III, respectively. The public expenditure in the transport sector at the NUTS III level (see Fig. 6) is found to be heavily dispersed (the C.V. is significantly larger than unity for all modes), in comparison to the public expenditure taking place at the NUTS I level (see Fig. 5). At both levels (particularly that of NUTS III), the road expenditure demonstrates low variability in relation to the expenditure in other modes. This fact reflects the overall increased importance of road infrastructure as well as the fact that it serves space more continuously than the other modes.

The public expenditures in railways and, in particular, urban public transport exhibit the highest variability. This spatial variability can be mainly attributed to the geographical constraints associated with the development of rail infrastructure in island and mountainous regions, and institutional constraints related to the private urban and inter-urban bus services outside Attica. The values of C.V. for public expenditures in airports and seaports present considerable fluctuations with opposing trends during the study period. The reduced spatial variability of airport and seaport expenditures, especially in comparison to railway expenditure, reflects the important geographical peculiarities of the country (mountainous terrain and scattered island complexes), which render both airplane and ferry as indispensable modes of communication. Thus, roads, airports and seaports are associated with higher levels of spatial balance in their spending than the other types of investment, although the interregional dispersion of rail expenditure has considerably decreased during the last years.

5. Empirical Results

This Section describes the results obtained from the application of the empirical models of the study. The findings of the interregional and local inter-modal expenditure competition models, based on data at the NUTS I level of aggregation, are first presented in Subsections 5.1 and 5.2. The analysis emphasizes on and more extensively discusses the findings of the global inter-modal expenditure competition model, which is based on the use of data at higher (NUTS II and NUTS III) levels of spatial resolution, in Subsection 5.3.

5.1 Interregional competition of transport expenditures

The interregional expenditure competition model allows identifying positive and negative geographical spillover effects of transport investment in specific modes. In this way, the model can provide insight into the concentration (or diffusion) impacts of a particular investment in a region on the investment of other regions (e.g., from core to peripheral regions, and vice versa) and, hence, implication of transport investment policy for regional cohesion. Table 1 shows the estimated coefficients (relative elasticities) of the interregional expenditure competition model (setting the Attica Region as the numeraire or reference Region). Each block demonstrates the impact of the growth of expenditure shares of the column regions on that of the row regions, for a particular type of transport investment.

The road expenditure is found to result in the largest (both in magnitude and statistical significance) interregional competition, compared to the other types of transport investment. More specifically, the expenditure in road infrastructure is substitutive between all Regions except for that of Central Greece. This is possibly due to the central position of the latter Region, which can accommodate a significant amount of transit road traffic flows from and towards the Region of Attica. In contrast, the public expenditures in the interregional and other transport facilities, including railways, airports, seaports (except for the growth of the share of the North Region) and urban mass transit, mostly exhibit complementary interregional relationships.

These results verify existing evidence that enhancement of regional accessibility through development of road infrastructure does not usually comply with the objective of regional cohesion or reduction of regional disparities (e.g., see Argyris and Kostopoulou, 2000), and mainly benefits the core region (i.e., Attica) (also see Martin, 2000). On the other hand, investment in interregional and public transport facilities can largely enforce the positive geographical spillovers and foster the synergistic effects in the strategic transport infrastructure planning of the Development Regions.

Table 1. Estimated coefficients of the interregional expenditure competition model

		Roads					Railways				Airports					Seaports					Urban Public Transport			R-sq
		North	Central	Attica	Aegean	Interregional	North	Central	Attica	Interregional	North	Central	Attica	Aegean	Interregional	North	Central	Attica	Aegean	Interregional	North	Attica	Interregional	
Roads	North	-7.713**	0.459	-1.202**	-1.483	-8.399*																		0.763
	Central	-6.474**	3.240	-1.055**	-1.777	-5.500																		0.817
	Aegean	-6.697**	5.010	-1.215**	-2.810	-4.160																		0.832
	Interregional	-8.029**	2.588	-1.309**	-2.555	-5.899*																		0.916
Railways	North						0.019	0.316	0.775	-2.553														0.217
	Central						0.912**	2.008**	1.799	5.977														0.626
	Interregional						0.216	0.813	-0.054	0.687														0.665
Airports	North										0.486**	1.139**	0.029	0.485**	0.524**									0.996
	Central										1.148**	0.646**	0.170**	-0.395**	0.724**									0.999
	Aegean										1.068**	1.133**	0.263*	-0.457*	0.838**									0.990
	Interregional										0.819**	1.354**	0.244**	0.126	0.571**									0.999
Seaports	North															-0.370	-11.612**	-2.541**	-1.403	-4.555*				0.979
	Central															0.393	1.165	0.534	2.077	2.804				0.857
	Aegean															0.622**	1.143	0.487*	1.920**	5.216*				0.992
	Interregional															0.507**	1.212	0.438	2.460**	8.249*				0.961
Urban Public Transport	North																				0.649	3.485	0.247	0.186
	Interregional																				-1.077	7.583	0.637	0.675

Note: (*) indicates 0.05<*p*-value<0.1, (**) indicates *p*-value<0.05.

5.2 Local inter-modal competition of transport expenditures

The local inter-modal expenditure competition model allows identifying statistically significant (substitutive and complementary) relationships between the transport expenditures in different modes. As mentioned before, such analysis can facilitate the evaluation of transport investment policies with regard to the goals of enhancing inter-modality and promoting more environmentally friendly and energy efficient modes of transport. Table 2 shows the estimated coefficients (relative elasticities) of the local inter-modal expenditure competition model (setting the road as the numeraire or reference type of investment). Each block demonstrates the impact of the growth of expenditure shares of the column modes on that of the row modes, for a specific Region.

The effects of road expenditure on public expenditures in other types of transport investment are found to be mixed, dependent upon the particular Region and geographical scale of the investment. This outcome signifies the need for considering local-specific (unobserved or omitted) factors which influence the allocation of transport investments at a higher level of spatial resolution. Similarly, airport and seaport expenditures present substitutive as well as complementary effects on public expenditures in other modes. In all the cases examined, seaport expenditure is found to cut down rail expenditure. On the other side, rail expenditure is found to have positive effects on seaport and airport expenditures. The expenditure in urban public transport has positive effect on rail, airport and seaport expenditures.

In general, the inter-modal interaction of public expenditures allocated to the North and the Aegean Regions presents mixed trends, while the substitutive relationships prevail over the complementary ones in the Central Region. In contrast, Attica Region and interregional investments (which attract the largest shares of public expenditure in the transport sector) mostly involve complementary inter-modal expenditure relationships. This outcome implies that agglomeration of activities promotes inter-modal investment policies. Also, large-scale, interregional transport investment projects can support the objectives of inter-modality as well as regional cohesion.

Table 2. Estimated coefficients of the local inter-modal expenditure competition model

		North					Central				Attica					Aegean			Interregional					R-sq
		Road	Rail	Air	Sea	Urban	Road	Rail	Air	Sea	Road	Rail	Air	Sea	Urban	Road	Air	Sea	Road	Rail	Air	Sea	Urban	
North	Rail	1.602	0.512*	-0.361*	-0.610**	0.131**																		0.849
	Air	-0.321	0.108	0.018	-0.174**	0.031*																		0.643
	Sea	3.218**	0.713**	-0.916**	-0.481*	0.052																		0.890
	Urban	2.714**	-0.206	-0.074	0.516**	-0.036																		0.866
Central	Rail						1.129	-0.035	-0.736**	-0.427														0.933
	Air						-6.377*	1.346	-0.86	-2.297														0.761
	Sea						-4.442	0.978	-1.117	-0.548														0.911
Attica	Rail										0.398	1.602	1.292	-0.605	0.049									0.703
	Air										0.384	-2.042	1.103	-0.17	0.007									0.924
	Sea										-0.058	0.467	0.647	-0.445	0.02									0.824
	Urban										0.386	0.603	1.126	-0.749	0.002									0.771
Aegean	Air															-0.996*	0.438**	0.575						0.759
	Sea															0.314	-0.173	-0.237						0.251
Interregional	Rail																		-0.926**	0.703**	0.065*	-0.059	0.015**	0.979
	Air																		0.263*	1.700**	-0.237**	5.345**	0.028**	0.996
	Sea																		-0.703**	1.399**	0.043	1.906**	0.038**	0.982
	Urban																		6.526**	-4.035**	-1.582**	2.002**	-0.220**	0.941

Note: (*) indicates 0.05<p-value<0.1, (**) indicates p-value<0.05.

5.3 Global analysis of inter-modal expenditure competition

In the global inter-modal expenditure competition model, its panel structure which highlights the cross-sectional nature of the transport investment allocation problem becomes a salient feature of the estimation methodology, as described in Subsection 3.3. The cross-sectional information principally corresponds to public expenditure data for each specific Prefecture (NUTS III). It also includes a few cross-sections which refer to public expenditure in interregional (between Prefectures – NUTS III and between Regions – NUTS II) transport projects as well as cross-country transport projects, which cannot be specified to particular regional entities. Fixed effects concerning the latter projects are used as the base (or reference) group dummy variable for assessing (through the use of the constant term) the effect of the other, region-specific dummies on the share growth of public expenditure in each mode.

For comparison purposes, the global inter-modal expenditure competition model is applied by using cross-sectional data at the Regional (NUTS II) level as well as the Prefecture (NUTS III) level. In the former case, the panel dataset is composed of 4 (share growth equations) $\times$ 16 (cross-sections) $\times$ 8 (years) = 512 total observations, while in the latter case the dataset is composed of 4 (share growth equations) $\times$ 62 (cross-sections) $\times$ 8 (years) = 1984 total observations. Appendices I and II present the estimates of the dummy variables of the global inter-modal expenditure competition model at the Regional (NUTS II) and Prefecture (NUTS III) level, respectively. At both of these levels, the spatial fixed effects in each equation of the expenditure growth share system are statistically different from zero, based on the joint Wald test, which provides theoretical justification of the use of the LSDV approach.

The sign and/or statistical significance of the spatial dummy variables denote some opposing trends in the interregional allocation of public investment in the Greek transport sector. More specifically, concentrating on the results of the Regional (NUTS II) level of analysis, the spatial fixed effects of the most highly urbanized regions of the Attica and Central Macedonia on the share growth of rail expenditure are found to be opposite with those of the rest (peripheral) regions. The spatial fixed effects of the Attica region on the share growth of airport expenditure are also opposite with those of the other regions, while the most statistically significant (positive) effects are observed in the island regions. Statistically significant and positive fixed effects on the share growth of seaport expenditure are also found in the island regions as well as in mainland regions with important hub-seaport facilities (i.e., Attica, Epirus, and East Macedonia and Thrace), in contrast with the corresponding negative fixed effects of the other mainland regions.

Last, statistically significant positive fixed effects on the share growth of urban public transport expenditure are primarily found in the island regions and most economically deprived regions of the country, such as Epirus, and East Macedonia and Thrace, where private bus owners receive subsidies (included in the category of cross-country public transport expenditure) to support their fleet development, renewal and operation. The statistical significance of the time-specific fixed effects manifests that temporal variations have a considerable impact on the allocation of public investment in the Greek transport sector. Nonetheless, this statistical significance vanishes for the cases of airport and seaport expenditures at the Prefecture (NUTS III) level of analysis.

Tables 3 and 4 show the estimated coefficients (relative elasticities) and equation statistics of the panel DS model at the Regional (NUTS II) and Prefecture (NUTS III) level, respectively. Each column refers to the coefficients of the share growth equation of a specific type of transport investment in relation to road investment. The coefficients are generally found to be lower in magnitude than those obtained from the local inter-modal expenditure competition model (see Subsection 5.2). About half of the elasticity estimates are found to be statistically significant at the conventional levels of confidence, while the results of the Durbin-Watson (D-W) test statistics demonstrate that there is no problem of serial correlation in the equations, at both levels of spatial analysis.

As was expected, the expenditure in road infrastructure has a negative effect on the growth of the expenditure share of all the other modes, particularly the rail and seaport. This effect, which verifies the substitutive relationship of road with respect to other transport infrastructures, becomes statistically significant for all types of investment at the higher (Prefecture – NUTS III) level of spatial analysis (see Table 4). As was also expected, the public expenditure in a specific mode has a statistically significant positive effect on the future growth of the expenditure share of that mode (except for urban public transport). This outcome denotes the scale effects of investing on a particular type of transport infrastructure, and justifies the dynamic expression of the present model. It can be attributed to the technical and systemic characteristics of such infrastructure, including indivisibility, which usually implies increasing returns to scale.

Table 3. Estimated coefficients and equation statistics of the panel-type DS model at the Regional (NUTS II) level

Mode	*Rail*	*Airport*	*Seaport*	*Urban PT*
Road	-0.218**	-0.179	-0.195	-0.181*
Rail	0.507**	0.080	-0.225	-0.019
Airport	0.161	0.378**	0.336**	0.049
Seaport	0.148**	0.152*	0.565**	-0.009
Urban PT	0.088**	0.037	0.005	0.055
R^2	0.660	0.688	0.655	0.725
Std .error	1.599	1.879	1.953	1.534
D-W test	1.729	2.054	1.936	1.720

Note: (*) indicates 0.05<*p*-value<0.1, (**) indicates *p*-value<0.05.

Table 4. Estimated coefficients and equation statistics of the panel-type DS model at the Prefecture (NUTS III) level

Mode	*Rail*	*Airport*	*Seaport*	*Urban PT*
Road	-0.154**	-0.116**	-0.181**	-0.146**
Rail	0.364**	0.063	-0.062	0.045
Airport	0.211**	0.385**	0.313**	0.189**
Seaport	-0.025	0.061	0.369**	-0.062
Urban PT	0.013	0.021	-0.007	0.035
R^2	0.475	0.455	0.487	0.539
Std .error	1.834	1.956	1.928	1.749
D-W test	2.042	2.116	2.088	2.029

Note: (*) indicates 0.05<*p*-value<0.1, (**) indicates *p*-value<0.05.

Most of the relationships between public expenditures in non-road infrastructure (including urban public transport) are found to be complementary. Especially, airport expenditure has synergistic effects on all other types of (non-road) transport infrastructure. These effects are statistically significant for all types of investment at the higher (Prefecture – NUTS III) level of spatial resolution (see Table 4). They possibly reflect the outcome of government as well as EU-supported (by the European

Regional Development Fund and Cohesion Fund) operational programs, which have been adopted to sustain the long-term sustainable development of the national transport system, in accordance with the priorities set by the European Commission regarding the improvement of transport infrastructures (see CEC, 2001; CEC, 2006).

Such an operational program refers to the "Railways, Airports, Urban Public Transport" (*www.saas.gr*), which largely aims at integrating the specific means of public transport through developing/strengthening domestic interconnections, and improving the quality of their services. The complementarity relationship between airport and seaport expenditures indicates the importance of the combined development of these types of infrastructure for servicing the peripheral regions of the country, particularly islands (see also Spathi, 2005).

Table 5. Summary of the relative (with respect to road) substitution and complementarity relationships among public expenditures in different types of transport investment (in columns)

Mode	*Rail*	*Airport*	*Seaport*	*Urban PT*
Road	**S**	**S**	**S**	**S**
Rail	**C**	C	S	C
Airport	**C**	**C**	**C**	**C**
Seaport	S	C	**C**	S
Urban PT	C	C	S	C

Notes: (S) indicates substitution relationship; (*C)* indicates complementarity relationship.
Shadowed cells denote statistically significant relationship at the 5% level of confidence.
Results obtained with the use of NUTS III-level (Prefecture) data.

In contrast with the outcome of analysis at the Regional (NUTS II) level (see Table 3), the results obtained from the use of data at the Prefecture (NUTS III) level (see Table 4) demonstrate that all pair-wise inter-modal expenditure relationships are symmetric (either complementary or substitutive in both directions). In particular, all relationships are found to be symmetrically complementary, except of those between seaport and rail, and seaport and urban public transport, which are symmetrically substitutive (but not statistically significant). Table 5 outlines the complementarity and substitution relationships among public expenditures in different types of transport investment in Greece, based on the use of data at the finer (NUTS III) level of spatial resolution.

6. Conclusions

Transport traditionally constitutes an important infrastructure component influencing production. For this reason, there exists considerable pressure for investment in the transport sector. The assessment of fiscal (public expenditure) externalities among different types of transport investment should be an integral part of the strategic decision-making and impact analysis of infrastructure provision. The present results stress the importance of the supply of the appropriate type of transport infrastructure, in order to support the policy objectives of regional cohesion and inter-modality. In the case of Greece, it has been shown that investments on public transport facilities and large-scale interregional infrastructure projects can produce positive geographical spillovers and promote the aforementioned objectives.

Road expenditure, which by far dominates in the Greek transport sector, generally relates to statistically significant substitutions with expenditures in other types of transport investment. On the contrary, airports can be regarded as the most important type of investment to help enforce the development of non-road transport infrastructure in comparison to road infrastructure. Non-road (including urban public transport) expenditures were found to be symmetric and mostly complementary to each other. These results signify the emerging agglomeration effects, especially at higher (Prefecture – NUTS III) level of spatial resolution, between public transport (rail, airport, seaport, urban transit) facilities, in contrast with road infrastructure.

The few negative relationships between public transport investments can be largely attributed to physical (geographical) and institutional constraints pertaining to the development of transport networks at each Prefecture. In particular, they demonstrate the need for allocating public expenditure in the transport sector so that promote connectivity and interoperability between seaports and railways in the mainland, and strengthen the existing weak linkages between urban public transport and the non-road (rail, seaport and airport) transport infrastructure.

Therefore, policy-makers need to consider the intra-sectoral benefits of each transport investment and, when necessary, to coordinate or subsidize projects with significant positive fiscal externalities. In the light of the ongoing liberalization process in transport infrastructure and services, further work could encompass the expenditure competition between public and private (road, rail, port, airport, transit) investments. Last, the expenditure competition might be extended to additionally include other types of non-transport infrastructure investments, like those on communication and energy networks.

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Appendix I.

Estimates of the dummy variables of the panel-type DS model at the Regional (NUTS II) level

Variable	*Rail*	*Airport*	*Seaport*	*Urban PT*
constant	-0.422	-1.229*	-0.385	-1.681**
att	-6.291*	-1.890	0.525	1.145
cgr	0.834	0.566	-0.482	0.680
cma	-1.712**	2.026**	-3.468**	0.282
cre	0.251	2.184**	-0.263	1.547**
emt	1.699*	1.934*	0.941	2.443**
epi	0.099	1.109	0.236	1.393**
ion	2.893**	5.555**	2.004*	4.312**
nag	3.593**	5.430**	2.783**	4.854**
pel	0.974	0.706	-0.407	0.894
sag	2.888**	5.866**	2.888**	4.463**
the	0.201	2.854**	-0.335	1.663**
wgr	-0.889	0.906	-0.102	0.771
wma	-0.285	0.683	-0.621	0.694
time	-0.225**	-0.241**	-0.154*	-0.169**
Joint Wald test (χ^2, *p*-value)	(43.726) 0.000	(53.825) 0.000	(33.386) 0.002	(46.548) 0.000

Notes: (*) indicates 0.05<*p*-value<0.1, (**) indicates *p*-value<0.05. *att:* Attica, *cgr*: Central Greece, *cma:* Central Macedonia, *cre*: Crete, *emt:* East Macedonia and Thrace, *epi*: Epirus, *ion*: Ionian Islands, *nag*: North Aegean, *pel*: Peloponnesus, *sag*: South Aegean, *the*: Thessaly, *wgr*: Western Greece, *wma*: Western Macedonia. Base dummy: interregional and cross-country investments.

Appendix II.

Estimates of the dummy variables of the panel-type DS model at the Prefecture (NUTS III) level

Variable	*Rail*	*Airport*	*Seaport*	*Urban PT*
constant	-0.448	-1.775**	-0.831*	-2.140**
aha	0.169	2.337**	1.677**	2.162**
ale	0.239	2.068**	0.453	1.828**
arg	1.353*	2.662**	1.315	2.921**
ark	0.867	2.091**	1.155	2.424**
art	3.107**	4.425**	3.327**	4.684**
att	0.757	-0.292	1.453	2.711
cgr	3.138**	4.387**	3.321**	4.653**
chi	0.704	2.071**	0.837	2.257**
cma	1.742**	3.631**	2.446**	3.892**
cre	0.353	1.560*	0.652	1.906**
cyk	0.722	2.007**	0.487	2.238**
dod	3.057**	5.500**	3.405**	4.677**
dra	3.266**	4.613**	3.466**	4.850**
ede	1.803**	2.685**	1.687**	2.990**
emt	5.157**	6.914**	5.541**	7.101**
epi	1.546*	2.824**	1.795**	3.115**
eto	0.201	1.387*	0.514	1.749**
evi	2.611**	3.912**	2.843**	4.184**
evr	3.691**	5.039**	3.889**	5.275**
flo	1.861**	3.130**	2.117**	3.428**
fok	3.697**	5.192**	3.267**	5.208**
gre	-0.104	1.095	0.201	1.447**
hal	2.190**	3.500**	2.444**	3.762**
han	2.961**	4.157**	1.605*	4.437**
igo	1.903**	3.078**	2.532**	3.514**
ili	1.668**	2.932**	1.870**	3.228**
ima	1.344*	2.610**	1.602*	2.910**
ioa	0.237	1.461*	0.533	1.791**
ira	3.205**	5.151**	2.826**	4.813**
kas	0.813	2.342**	1.054	2.381**
kav	3.288**	2.558**	3.081**	4.769**
kef	2.256**	3.553**	2.685**	3.805**
ker	2.978**	4.367**	2.760**	4.550**

Appendix II. (continued)

Variable	*Rail*	*Airport*	*Seaport*	*Urban PT*
kil	0.412	2.874**	1.760**	3.144**
kor	1.585**	1.647**	0.879	2.013**
koz	1.558**	2.816**	1.821**	3.122**
lak	2.102**	3.481**	1.688**	3.632**
lar	1.385*	3.357**	2.245**	3.648**
las	4.166**	5.999**	4.659**	5.730**
lef	1.467*	2.705**	1.745**	3.027**
les	3.816**	4.391**	3.917**	5.352**
mag	-0.426	3.682**	0.491	2.560**
mes	3.314**	4.663**	3.654**	4.881**
pel	0.411	1.706**	0.676	2.028**
pie	0.360	2.023**	0.649	2.288**
pre	2.128**	3.552**	2.353**	3.703**
pth	0.486	0.393	-0.238	0.794
ret	1.521*	2.809**	1.763**	3.092**
rho	2.768**	4.058**	3.007**	4.339**
sal	-2.130**	1.868**	-2.797**	0.172
sam	0.516	2.456**	0.320	2.070**
ser	2.711**	4.068**	3.105**	4.272**
the	1.089	3.034**	1.974**	3.329**
tri	0.610	2.289**	1.291	2.606**
vio	2.649**	3.958**	2.876**	4.225**
wgr	0.578	2.081**	1.094	2.405**
wma	0.951	1.977**	1.082	2.318**
xan	4.069**	5.432**	4.257**	5.656**
zak	0.389	3.168**	0.507	1.983**
time	-0.102**	-0.070	-0.064	-0.064*
Joint Wald test (χ^2, *p*-value)	(160.544) 0.000	(139.150) 0.000	(149.363) 0.000	(163.341) 0.000

Note: (*) indicates 0.05<*p*-value<0.1, (**) indicates *p*-value<0.05. *aha*: Achaea, *ale*: Evros, *arg*: Argolis, *ark*: Arcadia, *art*: Arta, *att*: Attica, *cgr*: Central Greece, *chi*: Chios, *cma:* Central Macedonia, *cre*: Crete, *cyk*: Cyclades, *dod*: Dodecanese, *dra*: Drama, *ede*: Pella, *emt:* East Macedonia and Thrace, *epi*: Epirus, *eto*: Aetolia-Acarnania, *evi*: Euboea, *evr*: Evrytania, *flo*: Florina, *fok*: Phocis, *gre*: Grevena, *hal*: Chalkidiki, *han*: Chania, *igo*: Thesprotia, *ili*: Elis, *ima*: Imathia, *ioa*: Ioannina, *ira*: Heraklion, *kas*: Kastoria, *kav*: Kavala, *kef*: Kefalonia, *ker*: Corfu, *kil*: Kilkis, *kor*: Corinthia, *koz*: Kozani, *lak*: Laconia, *lar*: Larissa, *las*: Lasithi, *lef*: Lefkada, *les*: Lesvos, *mag*: Magnesia, *mes*: Messinia, *pel*: Peloponnesus, *pie*: Pieria, *pre*: Preveza, *pth*: Phthiotis, *ret*: Rethymno, *rho*: Rhodope, *sal*: Thessaloniki, *sam*: Samos, *ser*: Serres, *the*: Thessaly, *tri*: Trikala, *vio*: Boeotia, *wgr*: Western Greece, *wma*: Western Macedonia, *xan*: Xanthi, *zak*: Zakynthos. Base dummy: interregional and cross-country investments.

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