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Measurement of intra- and inter-sectoral dependencies of public investments with budget constraints

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Measurement of intra- and inter-sectoral dependencies of public investments with budget constraints

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Abstract

The public-sector investment decision-making processes typically involve multiple and interrelated sectoral and regional policy objectives and budget constraints. These interrelationships may have a significant effect on future state funding needs and the strategic assessment of infrastructure development at the country level. This paper presents a dynamic spatio-economic model that considers both intra- and inter-sectoral investment dependencies under various types of budget constraints. The study employs the rich database of the Monitoring Information System of the Greek government concerning all public investment projects co-funded by the European Commission at the Prefecture level in the decade 2000-2009. The expenditure allocation dynamics of most types of public investment are found to be competitive with each other, due to lack of coordination, technological and budgetary constraints, geographical factors, and equity and political considerations. The deviations from criteria of economic efficiency rely on the timing, location and type of investment. There is evidence of significant scale effects and only limited and mostly asymmetric complementarities among the expenditures in public transport modes, and between those in energy and transport, information and communication technologies and R&D projects, and the agri-food sector and the other sectors.

Μέτρηση των ενδό- και διακλαδικών εξαρτήσεων των δημοσίων επενδύσεων υπό εισοδηματικούς περιορισμούς

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Περίληψη

Η διαδικασία λήψης αποφάσεων για την χωρική και κλαδική κατανομή των δημοσίων επενδύσεων συνήθως εμπεριέχει πολλαπλούς και αλληλένδετους στόχους και περιορισμούς. Αυτές οι αλληλεπιδράσεις μπορεί να έχουν σημαντική επίπτωση στις μελλοντικές ροές δαπανών και ανάγκες για επενδύσεις, και στην αξιολόγηση της ανάπτυξης των υποδομών σε εθνικό επίπεδο. Η παρούσα εργασία παρουσιάζει ένα δυναμικό χωρικό-οικονομικό υπόδειγμα για την εξέταση των ενδοκλαδικών και διακλαδικών εξαρτήσεων των δαπανών για δημόσιες επενδύσεις υπό εισοδηματικούς περιορισμούς. Τα στοιχεία πηγάζουν από τη βάση δεδομένων του Ολοκληρωμένου Πληροφοριακού Συστήματος (ΟΠΣ) της ελληνικής κυβέρνησης και αφορούν όλες τις πραγματοποιηθείσες δαπάνες για επενδύσεις που έχουν χρηματοδοτηθεί από Ευρωπαϊκούς και εθνικούς πόρους κατά τη δεκαετία 2000-2009. Η ανάλυση διεξάγεται σε επίπεδο Νομού και περιλαμβάνει συνολικά έντεκα κατηγορίες δαπανών ή τύπους επενδύσεων: τους πέντε κλάδους του τομέα των μεταφορών, δηλαδή, οδούς, σιδηρόδρομους, αεροπορικές μεταφορές, θαλάσσιες μεταφορές και αστικές δημόσιες συγκοινωνίες, και έξι ευρύτερους τομείς που αναφέρονται στην ενέργεια, τις τεχνολογίες πληροφορικής και επικοινωνιών, την έρευνα και τεχνολογική ανάπτυξη, το περιβάλλον (συμπεριλαμβανομένου του τουρισμού και του πολιτισμού), τον αγροτοβιομηχανικό τομέα και τις κοινωνικές υποδομές. Οι σχέσεις κατανομής των δημόσιων επενδύσεων εντός του τομέα των μεταφορών και, ιδιαίτερα, μεταξύ των διαφόρων ευρύτερων τομέων είναι κυρίως ανταγωνιστικές. Αυτό το αποτέλεσμα μπορεί να αποδοθεί στην έλλειψη συντονισμού μεταξύ των επιμέρους πολιτικών, σε τεχνολογικούς και δημοσιοοικονομικούς περιορισμούς, σε απαιτήσεις κοινωνικής συνοχής, και σε γεωγραφικούς και πολιτικούς παράγοντες. Η σημασία κάθε ενός από τους παραπάνω παράγοντες ποικίλλει ανάλογα με την χρονική στιγμή, την τοποθεσία

και τον τύπο της επένδυσης. Οι δαπάνες για δημόσιες επενδύσεις διέπονται γενικά από σημαντικές θετικές οικονομίες κλίμακας. Υπάρχουν περιορισμένες και γενικά ασύμμετρες σχέσεις συμπληρωματικότητας. Αυτές εντοπίζονται κυρίως μεταξύ των δαπανών για παραγωγικές υποδομές, όπως από τις θαλάσσιες στις αεροπορικές μεταφορές, από την ενέργεια στις οδικές, σιδηροδρομικές και δημόσιες αστικές μεταφορές, από τις οδικές και δημόσιες αστικές μεταφορές στις θαλάσσιες μεταφορές, και από τις θαλάσσιες μεταφορές στις τεχνολογίες πληροφορικής και επικοινωνιών και στην έρευνα και τεχνολογική ανάπτυξη. Τέτοιου είδους υποδομές με θετικές δημοσιονομικές εξωτερικεύσεις θα μπορούσαν να συνθέσουν κατά προτεραιότητα ένα επενδυτικό πακέτο τόνωσης της οικονομίας, ώστε μελλοντικά να προσελκύσουν περαιτέρω επενδύσεις και να ενεργοποιήσουν τις οικονομίες συγκέντρωσης. Ενόψει και της νέας προγραμματικής περιόδου 2014-2020, κρίνεται σημαντική η θέσπιση ενός πιο συνεπούς, διαφανούς και συνεκτικού πλαισίου ενοποιημένης αξιολόγησης των δημοσίων επενδύσεων τόσο σε διατομεακό όσο και διαπεριφερειακό επίπεδο.

1. Introduction

Regions become increasingly interdependent at various spatial scales and sectoral levels, as reflects their reliance on interregional flows of labor and resources. At the same time, the interdependencies among various infrastructure systems are intensified by the needs to fulfill capacity requirements of rapid urbanization and the renewal of aging infrastructure networks. These spatial and sectoral interactions can be generally attributed to shifts in production and consumption patterns, advances in information and communication technologies and the development of transport infrastructure. The New Economic Geography (NEG) (Krugman, 1991; Fujita et al., 1999) has provided a solid theoretical framework for analyzing the role and new forms of interactions between regions and the impacts of spatial agglomeration on productivity, output, employment and other economic variables. These impacts mostly arise from increasing economies of scale and scope, knowledge spillovers, reduction of transport costs and network effects (e.g., Rosenthal and Strange, 2001; Gill and Goh, 2010; LaFountain, 2005; Fratesi, 2008; Vogiatzoglou and Tsekeris, 2013). The expected gains from agglomeration can support fiscal and planning policies that foster the geographic concentration of infrastructures belonging to different sectors.

In this policy context, coordinated and synergistic actions of stakeholders in different regions and sectors can take place, through combining selected types of infrastructure investments in a particular geographical area. For instance, the recently (as of 2011) launched funding plan of the European Commission titled "Connecting Europe" aims at creating common investment mechanisms to develop transport, energy and information and communication technology (ICT) infrastructure networks, especially at cross-border peripheries and bottleneck areas. In turn, such coordinated investments can help to develop interconnected corridors (e.g., of high-speed train, energy pipeline and super-fast broadband optical fibre networks), which will promote the efficient movement of passengers, energy loads and information flows with increased reliability, environmental sustainability and reduced investment risk. Besides, the new (of July 2012) European Commission initiative "Smart Cities and Communities - European Innovation Partnership" aims at funding joint investments in energy, transport and ICT, to deliver more innovative and efficient services and support the sustainable development in urban areas.

In those investment allocation processes, the European (or national) funding bodies may impose various constraints into specific types or groups of expenditure categories, in order to prioritize certain policy objectives and/or ensure fiscal, environmental, operational and other requirements. Moreover, the increasing fragmentation of decision-making mechanisms at various administrative levels and policy sectors requires the development of suitable methodological tools to help to identify and handle conflicting investment strategies and improve coordination.

The present paper addresses the above problem through the development and implementation of a multi-sectoral spatio-economic model with budget constraints. In the existing literature (see Banister and Berechman, 2003), public investment interdependencies are typically considered within each expenditure category (e.g., for road infrastructure) or, to a lesser extent, intra-sectorally, among expenditure categories of the same sector (e.g., among road, rail, seaport, airport and urban mass public transit in the transport sector). The current model extends a recently proposed one, built on the model of Dendrinos and Sonis (1988, 1990), for representing competitive/complementary relationships among public investments in a given (transport) sector (Tsekeris, 2011). Its main objective is to provide a theoretically sound and systemic framework for identifying and addressing public investment interdependencies among different sectors of the economy.

In this framework, the regional investment growth per sector is expressed as a function of the past own and other expenditure categories as well as demographic, economic and political factors in each region, at the administrative level of Prefecture. Section 2 reports the theoretical background and several efforts in modeling fiscal externalities of public investments. Section 3 describes the dynamic spatio-economic model of public investment interactions. Section 4 presents the dataset employed in the study. Section 5 shows and analyzes the results of the model under various budget constraints, and Section 6 summarizes and concludes stressing the policy implications of the empirical findings.

2. Fiscal externalities of public investments

The problem of public expenditure interdependencies has been typically addressed by use of intuitive judgment or some crude policy guidelines (World Bank, 1988). These are primarily relying on intense political negotiations, without employing formal economic analysis within a sound methodological/modeling framework. However, a framework for public expenditure allocation can be applied to better inform decision making on inter-sectoral investment planning and program evaluation. Initial attempts included in the literature primarily sought to evaluate inter-sectoral investment allocations based upon cross-country, time series regression analysis of growth, by adopting the same criteria to those used for intra-sectoral allocations (Pradhan, 1996). Such criteria usually concern the role of government versus the private sector, cost-benefit analysis and equity impacts.

The availability of enriched datasets from central government has fueled quite a few country-level analyses of investment allocations involving multiple expenditure categories, particularly in the transport sector. Lindsey (2007) describes examples of strategic decisions of public investment allocations on transport infrastructures. Especially, in Singapore, the strategic competition of central government investment decisions reflects as over-investments in airport capacity and mass rapid transit system in order to prevent competing investments (Phang, 2003; Barter, 2006). Feng and Hsieh (2009) developed a hybrid model integrating system dynamics, cognitive maps and sensitivity analysis in order to provide a practical solution for dealing with the complex relationships among investment variables within an urban transport system.

Furthermore, public economics models of fiscal externalities can account for strategic investment interactions among jurisdictions in two forms: (i) spillover models, where each jurisdiction chooses the level of a decision variable, but the jurisdiction is also directly affected by the variable chosen elsewhere, indicating the presence of spillovers, and (ii) resource flow models, where the jurisdiction is affected by the amount of a particular resource that resides within its borders (Brueckner, 2003; Solé-Ollé, 2006). These types of models typically focus on estimating jurisdictions' reaction functions and determining inter-jurisdictional dependencies and competition among state expenditures for specific categories, such as medical and pharmaceutical expenditures (Baicker, 2005; Borck et al., 2007; Lauridsen et al., 2010). Other models have concentrated on vertical expenditure interactions among jurisdictions at hierarchical administration levels (Esteller-Moré and Solé- Ollé, 2001).

The specification of the above models generally implies that one jurisdiction's spending in some expenditure category has the largest spillover for geographically proximate neighbors. However, expenditure externalities may diffuse quite far, even in case of localized infrastructure projects, considering the inhomogeneity and discontinuity of factor mobility. This is particularly relevant for countries with intense geographical peculiarities, like Greece (mountainous terrain and scattered island complexes). Namely, all the elements of a spatial weight matrix may be either null or positive and the model elasticities should capture both positive and negative externalities to more realistically measure multi-sectoral relationships for distinct expenditure categories.

Except of the competition and/or cooperation between regions for the design and implementation of public investments of the same type[1], such relationships should also be considered and tested for investments of different type within a specific sector as well as among different sectors. The latter task is particularly important in the light of current European and national investment policies in order to address several (institutional, financial, technical, environmental and other) difficulties arising in the planning and evaluation of systems composed of different types of infrastructure. This task goes further beyond the typical consideration of competition (or coordination) between facilities, gateways or corridors of the same sector, such as in transport for the cases of port competition, airport competition and toll road competition.

Existing studies have focused on examining these relationships among broad categories of capital spending (for infrastructure and social welfare). For example, negative tradeoffs have been identified between military (so called nonproductive) spending and economic and social investments and well-being (Deger, 1986; Borch and Wallace, 2010). Fukuyama et al. (2003) employed a computable general equilibrium (CGE) model to simultaneously represent investments in multiple interdependent infrastructures or sectors in the economy of a region. They showed that competition and coalition among urban jurisdictions improve efficiency, compared to the case of providing a sole monopolistic service in the transport sector. The impact of budget constraints on multi-sectoral investment decisions has been only implicitly addressed within the framework of CGE models.

Nagurney and Dong (2002) proposed the concept of 'super-networks' to capture interactions among transport, telecommunication, energy, and financial networks. Although this modeling framework is well-defined using generalized

[1] For instance, the Latin American transport projects, the Asian-Pacific transport corridors and the TEN-T projects (Vickerman, 2007).

network theory and variational inequalities, its calibration and application issues are not sufficiently addressed. Tsekeris and Vogiatzoglou (2011) suggested a spatial agent-based modeling framework for investigating the competitive conditions for the provision of local public goods, firm development and transport infrastructures in a system of regions. Nonetheless, this approach can be quite computationally intensive and practically difficult to be validated for realistic-size (country-wide) applications. Zhang and Peeta (2011) developed a multilayered network model with market-based interactions to investigate interdependencies of investments among different types of network industries. However, such types of models do not have a sound explanatory power to interpret the causality of investment interdependencies for policy purposes. The following section proposes a system-wide dynamic spatio-economic model of interdependent resource allocation at the country level, which can be validated, explain causality and explicitly incorporate budget constraints, allowing for fiscal spillovers among (sub-)sectors.

3. Spatio-economic model of public investment interactions

The proposed model relies on a sound theoretical framework, that is, the dynamic spatio-economic model of regional competition of Dendrinos and Sonis (1988, 1990). Tsekeris (2011) appropriately modified this model to consider substitution and complementarity relationships of public investments in the transport sector at the country level, through employing data at finer levels of sectoral analysis and spatial resolution. The modified model is extended here to consider the public investment interdependencies among all economic sectors and the effect of budget constraints, at various expenditure categories (or category groups).

Let y^t_{mr} denote the relative public spending (share), with regard to the total spending in all sectors M, for investment type (or category) m at a specific region r and time t. Also, let us assume that there are M types of investment (by sector or sub-sector) in that region. The expression of shares signifies that: (i) expenditures can relatively vary (in a synergistic or competitive manner) among (sub-)sectors and prefectures, and (ii) they are subject to budget constraints, either at the (sub-)sectoral or the national level. In the former case, the analysis applies separately to each group of (sub-)sectors whose budget is considered to be fixed; hence, the fiscal externalities are restricted within each group and no positive or negative interactions (budget spillovers) are allowed with (sub-)sectors of other groups. In the latter case, the analysis encompasses all (sub-)sectors and the fiscal constraint corresponds to a national total fixed budget.

The model follows a log-linear panel data formulation, which allows expressing both the spatial and multi-sectoral variability of expenditure shares. Also, it controls for problems of omitted variables and heterogeneity, incorporating time- and region-specific fixed effects. Based on the analytical derivation procedure described in the Appendix A1, the public investment allocation can be considered as a discrete system of distributional dynamics among economic sectors with budget constraints, which is specified as follows:

$$\ln y_{mr}^{t+1} - \ln y_{1r}^{t+1} = \ln A_m + \sum_{k=1}^{M'} a_{mk} \ln y_{kr}^{t} + \sum_{n=1}^{N} b_{mn} Z_n^{t+1} + \eta_{mr} S_r + \theta_m^{t+1} L^{t+1} + u_m ,$$
$$m = 2, 3, \ldots, M'; \quad k = 1, \ldots, M'; \quad r = 1, \ldots, R; \quad t = 1, \ldots, T \tag{1}$$

subject to $\sum_{k=1}^{M'} \sum_{r=1}^{R} y_{kr}^{t} = 1$, with $M' \le M$, and $0 < y_{kr}^{t} < 1$.

The above specification is simplified to include two cases: $M' = M$, where all sectors are considered in the analysis subject to national total fixed budget, and $M' < M$. In the latter case, M' denotes a group of sub-sectors (here, it refers to those composing the transport sector). This constraint signifies that the total share corresponding to that (transport categories) group remains fixed (per annum) throughout the period of analysis. Nonetheless, it is noted that the present specification and analysis can be well extended to encompass more than two distinct expenditure groupings, even involving more types of sectoral and temporal budget constraints.

A positive value of elasticity coefficient a_{mk} indicates synergistic effect, i.e. complementary growth in expenditure shares between the two types of investment, m and k. On the contrary, a negative value of a_{mk} shows a competitive relationship in the expenditure allocation between them. The constant coefficient $A_m > 0$ denotes the advantages of investing on sector m. The usage of numeraire (here, denoted as investment type 1) facilitates the representation of time-varying intra- and inter-sectoral expenditure interactions by modeling the relative growth share of investment in a specific category as a function of the past growth share of investment in that category and other categories.

In the above system of $(M'-1)$ fixed-effect panel regression equations, S_r are time-invariant region-specific dummies corresponding to each prefecture (r), and η_{mr} are the corresponding spatial dummy coefficients for each sector m, which account for unobserved or omitted heterogeneity. These coefficients may capture the influence of factors that do not vary over time (e.g., geographical location, land morphology and climate 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 sector m, which are common to all prefectures but vary across time (e.g., technological changes, and EU and national policies for the whole country). The vector Z_n refers to a set of additional explanatory (control) variables (Section 4) and c_{mn} are the corresponding coefficients. The term $u_m \sim N(0,\sigma^2)$ denotes the random disturbance of the share growth equation of each type of investment m. It is assumed to be serially uncorrelated and adds stochasticity to the expenditure allocation dynamics.

The present model (1) comprises 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 system-wide LSDV approach applied here constitutes a three-way model, which can appropriately treat the panel (fixed group and time) effects and variations by investment type of the current dataset in order to provide robust estimates. The estimator which is used to solve the model, that is linear in parameters, refers to the iterative method of Seemingly Unrelated Regressions (SUR) with fixed effects, which enables to capture time- and region-invariant effects specific to each sector.

The suggested modeling framework intrinsically implies a complementarity or competitive relationship between (distinct groups of) sectors or expenditure categories, whose overall budget is considered to be fixed and which seek to obtain the maximum possible share. This is in accordance with a zero-sum game, in which the growth in one agent (sector or group of sectors) takes place at the expense of, at least, one another, so that balance the total budget in the period of analysis. The elasticity terms a_{mk} may incorporate the impact of a set of interrelated or conflicting policy objectives of multiple agents (stakeholders) at various (sectoral and spatial) levels of decision-making. The resulting pattern of interaction and its significance would rely on which policy or technological forces of a specific agent will mostly prevail over (or cooperate with) the others.

On the one hand, a strategic investment in one sector may target at agglomerating infrastructure investments in other sectors in a specific region, e.g., through exploiting reductions in transport cost, input sharing, knowledge spillovers and economies of scale. Such investments typically support coordinated policy objectives and they can be implemented within collaborative programs focused on transport, energy, ICT and the environment to promote regional development. On the other hand, the net effect of a strategic investment on the other (targeted) types of investments at the country level could be negative (as would reflect the sign of a_{mk} coefficient), e.g., due to asymmetric changes in interregional accessibility and the production structure of the whole spatial economy. The lack of coordination among policies at the regional and sectoral levels may cause negative externalities or adverse budget spillovers among those types of investments.

4. Input variables and data sources

The study employs the rich database of the Monitoring Information System (MIS) of the Greek government concerning all public investment projects funded by the European Commission and the Public Investment Program of the country at the administrative level of Prefecture (NUTS III)[2] in the decade 2000-2009. This period coincides with the third programming period 2000-2006 of the Community Support Framework (CSF) and the first years of implementation of the National Strategic Reference Framework (NSRF) 2007-2013 of the European Union. During the study period, special attention was given to the completion of large-scale (transport, ICT and other) as well as localized infrastructure projects, to enhance regional growth and convergence, in accordance with the EU development and cohesion funding policies. The investment allocation process among (sub-)sectors and regions includes a multi-

[2] The NUTS (Nomenclature of Territorial Units for Statistics) classification is used in the Community legislation for the sub-national division of regions into 3 levels: Development Regions at NUTS I, Regions at NUTS II and Prefectures at NUTS III.

stage, hierarchical public consultation, with cross-scale interactions between various stakeholders (agents), as ministries, regional, provincial and municipal government agencies, (state or private) firms and non-government organizations, private-sector enterprise groups (lobbies), professional bodies and labor unions. This process takes place at different levels (action categories) of homogeneous investment groups, such as priority axes, (sub-)measures and (sub-)projects, to allow setting specific budget constraints, interchanging resources among categories, and performing the financial monitoring and evaluation of funding programs.

There is a total of eleven types of investments or expenditure categories. Regarding the transport sector, it is distinguished into five categories (sub-sectors): (i) roads (including bridges), (ii) railways, (iii) airports and aviation, (iv) seaports and maritime transport, and (v) urban public transport. The other types of investments refer to one of the following six categories: (vi) energy, (vii) Information and Communication Technologies (ICTs), (viii) Research and Development (R&D), (ix) social infrastructure and services, (x) environment (including culture and tourism), and (xi) agriculture and food industry. Table 1 describes in detail the expenditure sub-categories included in each type of non-transport investment. The various types of transport investments, together with those of energy, ICTs and R&D, constitute the main sources of planning, design and operation of infrastructure networks in the country.

All types of investments are expressed with the measure of expenditure, in terms of actual spending Euros. This measure can offer a more precise metric of the level of realized public investments, compared to the apportioned regional public capital stock data typically used in the literature (Sloboda and Yao, 2008). The expenditure data have been deflated at 2005 constant prices based on the government expenditure deflator of the Hellenic Statistical Authority (EL.STAT.). Table 2 presents the 2000-2009 period-average expenditure shares (%) by type of investment in Greece. Among all categories, social expenditure covers the largest share (31%), while road expenditure (23%), environmental expenditure (19%) and agri-food sector expenditure (17%) follow in order. Following the road works, ICTs, railway and seaport expenditure categories attract the largest shares of investment in physical infrastructure networks.

Table 1. Description of non-transport investment/expenditure categories

Type of investment/expenditure category	Description
Energy	Infrastructures for production and distribution of energy
Information and Communication Technologies (ICTs)	Development and exploitation of information systems, Information Society infrastructures for the culture and media events, education, tourism, public administration, health care and social welfare, transport, business competitiveness, agriculture, research & development, communication systems, environmental protection, cadastral system and Geographical Information Systems (GIS).
Research and Development (R&D)	Projects for research and technological development, services for promoting R&D, innovation and product quality, and infrastructures in industrial areas, technological parks, freight and exhibition centres.
Social infrastructure and services	Infrastructures in education, health and social welfare, expenditures for education, training and employment, public information and social awareness, human capital support, public safety and security, support of non-governmental organizations, and measures for gender equality and against social discrimination and employment inequalities.
Environment (incl. culture and tourism)	Projects for waste management, water supply, sanitation and wastewater

	treatment, flood prevention, irrigation, land reparcelling, museums, promotion and restoration of archeological sites and monuments, site regeneration, infrastructures, equipment and services for environmental protection, upgrading of habitats and ecologically sensitive areas, mountain paths and refuges, exploitation of caves, tourism and leisure infrastructure, upgrading and restoration of sites for industrial and military use.
Agriculture and food industry	Livestock, manufacturing, trade, standardization, safety and promotion of fishing, forest and agricultural products, forest restoration, agricultural electrification, fishing vessels, aquaculture, fishing port and auction centres and auxiliary facilities, development of farm enterprises and restoration of damages due to disasters/unexpected events, alternative investments in agricultural areas, innovation, development and protection of fishing resources.

Source: Own processing of the 3rd CSF expenditure dataset from the Monitoring Information System (MIS), Ministry of Economy, Competitiveness and Shipping. *Note*: The categorization excludes current expenses for budget administration and monitoring purposes and subsidies for individual firms.

The control variables are used in the model specification to address issues of causation in the investment allocation decisions. Except of the political variables (obtained from the Ministry of Interior), they are originated from the statistical database of the EL.STAT. and include: (a) *Population density*, defined as the ratio of the population of each prefecture to the land area (km^2) covered by the prefecture, (b) *GDP per capita*, which is the ratio of the Gross Domestic Product (GDP) corresponding to each prefecture to its population, (c) *Agricultural GVA share (%)*, i.e., the Gross Value Added (GVA) of the agricultural sector to the total GVA of the prefecture, (d) *Manufacturing GVA share (%)*, i.e., the GVA of the manufacturing sector to the total GVA of the prefecture, (e) *Cpu density*, that is, the ratio of equivalent car passenger units (cpu)[3] per inhabitant per km^2, which proxies congestion effects, (f) *tourists*, in terms of the (domestic and international) arrivals of visitors in each prefecture, and (g) political factors. Table 3 shows the matrix of correlations (and their statistical significance) between the model variables (except of political variables). The results show that the covariates are not highly correlated to each other (all correlation coefficients are found to be lower than 80%); hence, the inclusion of these variables is not expected to lead to biased estimates due to multicollinearity problems.

The political factors reflect public investment decisions where efficiency or equity considerations are neglected in favor of administrative and political objectives, according to the political system and behavior of voters. Three political variables are employed to demonstrate the possible impact of those factors. First, the *vote share* between government and main opposition party: on the one side, government may increase relative expenditure shares to those prefectures that voted in their favor in the preceding election (Cox and McCubbins, 1986); on the other side, an opposite effect might work when government decision makers may lose interest in those prefectures wherein they either dominate or have no chance of winning. Second, the parliamentary *seat difference* between the government and main opposition party in some prefecture may denote the role of electoral competition on relative spending shares, in terms of how 'publicly influential' each type of investment is. Third, the *electoral cycle*, in terms of the number of years until the next election, may also influence the sectoral, regional and temporal allocation of investment (Gärtner, 1994). In the study period, the two major political parties of the country, i.e. the socialist party (PASOK) and the liberal/conservative party (New Democracy) shared the time in power. PASOK was reelected in government in 2000, New Democracy won the elections of 2004 and 2007, and PASOK won the election of November 2009. Thus, a

[3] Equivalent cpu is defined as the weighted sum of all vehicles with traffic license, where the weight of (private or public use) passenger cars equals to 1, of two-wheel motorized vehicles equals to 0.5, of truck vehicles equals to 2.0 and of buses equals to 3.0, so that denote the relative impact of each type of vehicle on the level of traffic congestion, according to its geometric and operational characteristics.

value of zero is assigned to the dummy variable of political cycle in the years of 2000, 2004, 2007, 2009, which increases by one for each year away from the year of election.

Table 2. Average expenditure shares (%) by type of investment in Greece, 2000-2009

Prefecture	*Road*	*Rail*	*Air*	*Sea*	*Urban*	*Energy*	*ICT*	*R&D*	*Social*	*Envi*	*Agri*
Achaia	35.772	1.188	0.000	9.589	0.000	0.020	3.231	3.385	25.806	12.513	8.496
Argolida	12.488	0.000	0.000	2.755	0.000	0.049	3.649	0.523	34.282	27.538	18.716
Arkadia	26.770	0.000	0.000	1.063	0.000	0.038	2.539	1.381	29.149	19.096	19.963
Arta	18.161	0.000	0.000	0.000	0.080	0.055	3.265	1.676	40.306	13.669	22.788
Attiki	10.477	11.144	0.034	0.542	7.823	0.745	8.950	1.589	45.300	11.837	1.558
Chania	20.196	0.000	0.601	3.653	0.000	0.000	2.652	2.320	34.648	19.534	16.394
Chios	7.723	0.000	0.770	5.182	0.000	0.000	3.028	0.294	43.520	23.670	15.813
Cyklades	5.211	0.000	4.509	9.862	0.000	0.293	3.354	2.305	31.304	26.559	16.603
Dodekanisa	8.187	0.000	9.557	9.064	0.152	0.000	2.833	0.836	22.050	37.317	10.003
Drama	16.168	0.154	0.000	0.000	0.000	1.036	3.379	0.523	34.584	20.078	24.080
Etoloakarnania	34.743	0.000	0.793	1.274	0.000	0.033	1.848	0.999	24.629	19.317	16.364
Evia	26.207	1.887	0.145	3.637	0.000	0.157	3.201	2.172	29.695	15.830	17.069
Evritania	21.067	0.000	0.000	0.000	0.000	0.000	4.123	0.000	45.247	13.484	16.079
Evros	39.645	5.899	2.736	0.467	0.000	2.961	2.274	0.648	19.075	16.629	9.665
Florina	7.983	0.000	0.000	0.310	0.000	0.497	3.506	0.541	41.823	20.155	25.184
Fokida	12.820	0.000	0.000	0.413	0.000	0.069	4.828	0.181	33.702	28.026	19.959
Grevena	72.991	0.000	0.000	0.000	0.007	0.030	0.900	0.024	10.912	7.282	7.855
Halkidiki	19.555	0.000	0.000	4.604	0.000	0.041	2.591	3.600	25.101	17.059	27.450
Ilia	21.840	0.132	0.000	3.411	0.000	2.226	3.087	0.756	24.567	24.631	19.351
Imathia	30.737	5.799	0.000	0.000	0.014	0.125	3.336	1.442	24.073	11.368	23.105
Ioannina	68.853	0.000	0.000	0.034	0.000	0.011	1.062	1.896	15.372	7.215	5.558
Iraklio	27.780	0.000	2.257	0.699	0.000	0.000	3.774	3.735	23.971	25.177	12.607
Karditsa	16.803	0.000	0.000	0.000	0.000	0.440	3.835	1.342	36.048	21.717	19.815
Kastoria	11.351	0.000	9.689	0.000	0.014	0.110	2.414	1.286	35.852	22.321	16.963
Kavala	44.006	0.000	0.000	2.367	0.000	0.142	1.954	1.500	26.001	12.263	11.765
Kefalonia	10.156	0.000	0.246	4.003	0.000	0.068	3.268	0.812	36.867	20.332	24.249
Kerkira	10.380	0.000	1.296	5.665	0.000	1.873	3.136	0.764	47.750	22.370	6.767
Kilkis	9.384	10.862	0.000	0.000	0.000	0.826	2.726	1.311	31.943	20.223	22.725
Korinthia	11.127	4.020	0.000	2.457	0.000	1.687	3.611	1.136	32.712	17.563	25.688
Kozani	38.915	0.000	0.000	0.535	0.085	0.243	4.194	1.047	23.896	15.176	15.909
Lakonia	21.100	0.000	0.000	1.012	0.000	0.048	3.174	0.408	37.831	19.487	16.939
Larisa	29.325	7.077	0.000	0.766	0.000	0.408	2.348	0.985	20.730	27.055	11.306
Lasithi	16.270	0.000	5.539	0.964	0.000	0.131	2.942	1.789	29.362	18.925	24.078
Lefkada	15.292	0.000	0.000	10.041	0.000	0.086	4.634	0.223	40.373	18.909	10.442
Lesvos	11.958	0.000	0.684	3.433	0.000	0.000	3.416	1.399	33.481	25.544	20.086
Magnisia	28.501	0.055	3.162	3.179	0.000	0.248	2.004	1.737	26.226	25.046	9.840
Messinia	16.069	0.000	0.000	2.535	0.000	0.040	6.517	1.430	37.408	20.220	15.781
Pella	10.117	4.578	0.000	0.000	0.000	0.039	4.136	1.489	33.814	18.244	27.583
Pieria	35.748	9.053	0.000	1.077	0.000	0.294	1.492	0.446	23.703	12.617	15.570
Preveza	12.431	0.000	0.000	0.167	0.046	0.054	3.947	0.269	39.323	21.959	21.804
Pthiotida	23.177	39.923	0.000	0.275	0.021	0.163	0.817	0.354	15.035	9.528	10.707
Rethymno	16.998	0.000	0.000	2.644	0.000	0.000	2.626	1.974	29.832	22.527	23.400
Rothopi	31.191	0.128	0.000	0.000	0.083	4.001	6.552	1.300	29.574	15.692	11.478
Samos	11.190	0.000	10.334	9.019	0.059	0.000	2.741	0.231	31.187	15.198	20.043
Serres	31.777	0.865	0.000	0.000	0.000	0.387	3.684	1.684	28.319	11.733	21.551
Thesprotia	14.428	0.000	0.000	0.712	0.000	2.266	3.149	0.004	38.100	15.904	25.438
Thessaloniki	27.901	12.441	6.307	0.122	0.013	0.167	7.239	3.231	24.678	10.118	7.782
Trikala	23.983	0.257	0.000	0.000	0.000	0.447	3.507	0.297	33.205	14.275	24.030
Viotia	33.201	9.826	0.000	0.168	0.000	1.432	2.403	2.208	21.552	19.432	9.778
Xanthi	38.083	0.157	0.000	0.493	0.000	0.585	2.544	3.372	27.197	14.762	12.806
Zakynthos	5.417	0.000	8.711	1.314	0.000	7.134	3.475	0.667	35.701	18.692	18.890
Average	**22.581**	**2.460**	**1.321**	**2.147**	**0.165**	**0.622**	**3.331**	**1.285**	**30.722**	**18.545**	**16.821**
St. Dev.	**14.216**	**6.360**	**2.814**	**2.891**	**1.094**	**1.253**	**1.477**	**0.969**	**8.121**	**5.895**	**6.354**

Source: Own processing of the 3rd CSF expenditure dataset from the Monitoring Information System (MIS), Ministry of Economy, Competitiveness and Shipping.

Table 3. Matrix of correlations between the model variables

	Road	*Rail*	*Air*	*Sea*	*Urban*	*Energy*	*ICT*	*R&D*	*Social*	*Envi*	*Agri*	*Density*	*GDP capita*	*Agri GVA*	*Manuf GVA*	*Cpu density*	*Tourist*
Road	1																
Rail	-0.06	1															
Air	-0.13*	-0.04	1														
Sea	-0.16*	-0.11*	0.07	1													
Urban	-0.06	0.12*	-0.04	-0.05	1												
Energy	-0.09	-0.03	0.03	-0.02	-0.03	1											
ICT	-0.19*	0.046	-0.018	-0.02	0.14*	-0.00	1										
R&D	-0.11*	0.02	-0.07	0.09	0.01	-0.05	0.16*	1									
Social	-0.53*	-0.21*	-0.03	-0.07	0.04	0.02	0.03	-0.05	1								
Envi	-0.43*	-0.15*	-0.07	0.13*	-0.07	-0.05	0.06	0.09*	-0.05	1							
Agri	-0.38*	-0.16*	-0.05	-0.08	-0.11*	-0.04	-0.13*	-0.03	-0.10*	-0.06	1						
Density	-0.09*	0.17*	-0.00	-0.04	0.67*	0.00	0.26*	0.08	0.13*	-0.10*	-0.21*	1					
GDP capita	-0.09*	0.18*	0.08	0.16*	0.15*	0.02	0.07	0.25*	-0.15*	0.24*	-0.18*	0.24*	1				
Agri. GVA	-0.01	0.008	-0.15*	-0.27*	-0.15*	0.04	-0.15*	-0.18*	0.13*	-0.16*	0.25*	-0.31*	-0.55*	1			
Manuf. GVA	0.16*	0.17*	-0.13*	-0.12*	-0.02	-0.04	-0.00	0.11*	-0.17*	-0.06	-0.04	-0.03	0.41*	-0.08	1		
Cpu density	-0.25*	-0.13*	0.15*	0.23*	-0.04	0.15*	0.04	-0.12*	0.18*	0.12*	0.00	0.01	0.18*	-0.28*	-0.33*	1	
Tourist	-0.13*	0.11*	0.10*	0.09*	0.53*	-0.00	0.23*	0.14*	0.04	0.07	-0.21*	0.76*	0.35*	-0.39*	-0.12*	-0.05	1

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

5. Results

5.1 Investment competition model with sectoral budget constraint

In the first set of experiments, the public investment interdependencies are examined separately among the transport and the non-transport expenditure categories, by assuming a fixed total budget in the transport sector (i.e., no budget spillovers are allowed with other sectors). The dependent variable of the intra-sectoral (within transport) competition model is expressed as the ratio of non-road transport expenditure to road expenditure (i.e., road is the numeraire or reference category). This ratio can provide a plausible metric of the inter-modal equity or investment balance, in terms of jointly promoting more sustainable (non-road) means of transport.

Table 4 shows the results of the intra-sectoral investment competition model for transport expenditure categories. Each column refers to the coefficients of the share growth equation of a specific type of investment. Table 5 reports the results of the inter-sectoral investment competition model (among all types of investment excluding those of the transport sector). In the latter model, the agri-food sector expenditure is used as numeraire. Hence, the coefficients denote the competing or complementary (de-)investment in sectors related to construction and services (i.e., other than those in the agri-food sector). Besides, the values of road, agri-food and social expenditures are non-zero for all prefectures in the study period, which practically facilitates their use as numeraire.

The model of transport investment interactions (Table 4) signifies the existence of statistically significant relationships, which are either competitive (due to road investment) or synergistic (among non-road transport categories, principally, due to seaport investment). The latter outcome possibly demonstrates the ability of sea gateways and maritime corridors to enhance the concentration of economic activities in their vicinity in order to promote the agglomeration of public transport infrastructure and combined transport operations. The complementarities among non-road transport expenditures can be explained by the need for balancing the total amount of transport investment as a zero-sum game, through the cooperation of lower-budget transport categories against road expenditure. There are also statistically significant effects of transport investment in the same category (except for urban public transport), which can be attributed to increasing scale effects pertaining to the technical and systemic characteristics of these infrastructures (e.g. indivisibilities and continuation of projects across consecutive years).

Regarding the interaction patterns among non-transport expenditure categories (Table 5), there are statistically significant interrelationships which are mostly competitive. The statistically significant complementarity relationships are only a few, including the effect of ICT on R&D expenditure and of social expenditure on energy expenditure. Furthermore, there are statistically significant positive own-expenditure (scale) effects on energy, R&D and environment, but these are negative for ICT expenditure. In addition to their technical and systemic features, the presence of scale effects in transport and other (physical) infrastructures may be also related to efficiency criteria.

These criteria reflect the need to increase the productivity of past public investments in selected areas and treat time persistent problems of the regional economies. In the same line, MacKay (2001) observed significant inertia in the allocation of public investments in the U.K. and argued that this is driven, to a large extent, by 'custom and practice'. This 'path-dependence' of investment distributional dynamics may be particularly important when there is uncertainty about the optimal allocation of resources (MacKay and Williams, 2005; Midwinter, 2004) or a strong influence of history and physical/economic geography (Costa-Font and Rodriguez-Oreggia, 2006). The impact of time- (year-) and prefecture-specific fixed effects and control variables on the share growth of each expenditure category are presented in detail in the next subsection.

Table 4. Results of the intra-sectoral investment competition model

	Rail	*Air*	*Sea*	*Urban*
Road	-0.249***	-0.277***	-0.096	-0.268***
Rail	0.329***	0.061	0.037	0.078**
Air	0.041	0.409***	0.067	-0.006
Sea	0.076**	0.119***	0.440***	0.056*
Urban	-0.105	-0.077	0.153	0.028
Pop. Density	0.016	0.022	0.009	0.018*
GDP capita	-0.048	-0.132**	0.083	-0.038
Agri. GVA %	-0.009	-0.053*	0.036	-0.012
Manuf. GVA %	-0.010	0.025	-0.062	0.010
Cpu density	-1.260	-2.847**	1.815	-0.256
Tourists	1.001*	0.229	1.180	-0.631
Gov. Vote %	-0.024*	-0.014	-0.020	-0.019**
Seat. Diff.	0.037	0.161***	0.069	0.052
Pol. Cycle	-0.025	-0.006	-0.025	-0.026
Year effect	0.037	-0.035	-0.029	-0.010
Constant	-0.892	4.738*	-6.824*	-2.236
Adj. R^2	73.625	63.756	56.809	54.300
Wald (overall)	8800.23 (0.000)	8090.37 (0.000)	3177.67 (0.000)	18446.79 (0.000)
Wald (FE)	258.13 (0.000)	103.89 (0.000)	86.53 (0.001)	80.08 (0.004)

Note: (***) indicates p-value<0.01, (**) indicates 0.01<p-value<0.05, (*) indicates 0.05<p-value<0.1

Table 5. Results of the inter-sectoral investment competition model (excluding the transport sector)

	Energy	*ICT*	*R&D*	*Social*	*Environment*
Energy	0.127**	0.012	-0.035*	-0.021*	-0.017
ICT	-0.193	-0.142***	0.160***	-0.084***	-0.174***
R&D	-0.057	-0.091**	0.263***	-0.019	-0.021
Social	0.931***	0.094	-0.137	0.006	-0.080
Environment	-0.618***	-0.160***	-0.038	-0.048	0.231***
Agriculture	-0.342*	-0.263***	-0.143**	-0.093**	-0.166***
Pop. Density	0.028	-0.013	0.001	-0.016	-0.024**
GDP capita	-0.238*	-0.019	-0.007	0.021	-0.029
Agri. GVA %	-0.048	-0.027	-0.001	0.005	0.016
Manuf. GVA %	-0.005	-0.050*	-0.085***	-0.045***	-0.032*
Cpu density	-2.380	-4.600***	-1.972*	-2.054***	-0.087
Tourists	2.641*	1.774***	0.738	0.786**	1.123**
Gov. Vote %	-0.110***	-0.056***	-0.003	-0.014*	-0.006
Seat. Diff.	0.406***	0.067	-0.015	0.005	-0.019
Pol. Cycle	-0.276**	0.118**	-0.163***	-0.138***	0.058*
Year effect	-0.032	0.087**	-0.095**	-0.170***	0.024
Constant	5.765	9.772***	1.878	6.901***	3.009*
Adj. R^2	36.588	47.024	54.494	69.517	48.462
Wald (overall)	211.98 (0.000)	397.32 (0.000)	710.00 (0.000)	544.58 (0.000)	431.28 (0.000)
Wald (FE)	77.52 (0.008)	107.88 (0.000)	225.52 (0.000)	111.93 (0.000)	114.00 (0.000)

Note: (***) indicates p-value<0.01, (**) indicates 0.01<p-value<0.05, (*) indicates 0.05<p-value<0.1

5.2 Investment competition model with overall budget constraint

This subsection investigates the public investment interdependencies in the presence of a fixed overall budget constraint, thus allowing budget spillovers between each distinct expenditure category (or investment type). Table 6 shows the results of the inter-sectoral investment competition model with agri-food sector expenditure as the numeraire variable and Table 7 the corresponding results with social expenditure as the numeraire variable. The former model is generally found to have a considerably higher number of statistically significant variables and better goodness of fit for more growth share equations, than the latter one. Hence, it can be regarded that the former model better explains the variability of the relative growth shares of public investments. However, all the statistically significant coefficients related to the expenditure categories as well as the control variables are found to have the same direction of impact (sign) on the corresponding growth shares in the two systems. This outcome verifies the robustness of the model with respect to the use of numeraire.

As in the models presented in subsection 5.1, the spatial fixed effects in each equation of the expenditure growth share system are found to be statistically different from zero (at the 95% level of statistical confidence), based on the joint Wald test. The only exception is the non-significant effect on urban public transport in the inter-sectoral investment competition model with social investment as the numeraire (Table 7). Thus, the local characteristics and comparative advantages of each prefecture have a significant impact on attracting public investments. However, it is noted that this impact can considerably vary, in terms of its direction (sign), among prefectures, depending on the level of urbanization and the geographical constraints met in several mountainous and island areas[4]. The time- (year-)specific effects are also generally found to be statistically significant on the relative allocation of public expenditure. The significance of these effects is particularly evident in the model with the social expenditure as the numeraire (Table 7).

The relaxation of the fixed budget constraint on the transport sector is found to increase the number of competitive (substitution) relationships among public transport expenditure categories. This is mainly due to the impacts of urban public transport

[4] The values of spatial fixed effects for each prefecture and type of investment are available from the author upon request.

expenditure and the substitution effects of rail and maritime expenditure on road expenditure. The inter-modal complementarity relationships, which are found to be statistically significant and non-symmetric, refer to those from road and urban public transport to maritime transport expenditure, from rail to urban public transport expenditure, and from maritime to air transport expenditure. Table 8 summarizes the results of the inter-sectoral investment competition model for both transport and non-transport expenditure categories.

As in the subsection 5.1, the results of all models suggest the significance of positive scale effects for most types of investments, except for urban public transport and social expenditure (non-significant) and ICT (negative). There is an evident prevalence of the competitive relationships among the various expenditure categories (more than half of them are statistically significant) over the complementarity relationships. Beyond the fiscal complementarities within the transport sector, there are positive effects of energy expenditure on road, rail and urban public transport and agri-food sector expenditure. The complementarities also concern the attraction of investment from all sectors to the agri-food sector, from maritime transport and ICT to R&D, and from social infrastructure and services to energy. Therefore, most of the fiscal complementarities are generated by the so-called productive infrastructure investments, especially those in energy and maritime transport.

The considerable number of significant substitution relationships arguably shows the existence of limited economies of scope in regional public investments. Namely, per-unit cost reductions through investing in one type of infrastructure are not widely associated with increasing the scale of production in other types of infrastructure. The lack of national and sub-national (among prefectures) policy coordination in the sectoral allocation of public expenditure can be regarded as a source of fiscal competition. For instance, the tendency for overinvestment in road projects can be partially seen as a mechanism to expedite the absorption of EU funds on a largely ad hoc basis. The failure of coordinating public investment programs is quite obvious in cases where expenditure complementarities among specific types of infrastructure were expected but not realized, such as from R&D to ICT and from urban public transport to rail and air transport.

Table 6. Results of the inter-sectoral investment competition model (with agriculture as the numeraire variable)

	Road	*Rail*	*Air*	*Sea*	*Urban*	*Energy*	*ICT*	*R&D*	*Social*	*Environment*
Road	0.354***	-0.031	-0.046	0.111*	-0.061	-0.440***	-0.310***	-0.130**	-0.033	-0.068*
Rail	-0.091*	0.228***	-0.049	-0.084	-0.016	-0.301***	-0.138***	-0.067*	-0.071***	-0.077**
Air	0.017	-0.010	0.314***	-0.035	-0.025	-0.316**	-0.032	-0.103*	0.005	0.014
Sea	-0.205***	-0.059	0.048	0.112**	-0.085**	-0.031	-0.108**	0.016	-0.047*	-0.044
Urban	-0.104	-0.211***	-0.185***	0.033	-0.082	-0.164	-0.093	-0.131*	-0.131***	-0.121**
Energy	0.027	0.022	0.003	0.009	0.004	0.105**	-0.001	-0.040**	-0.020*	-0.018
ICT	-0.009	-0.031	-0.045	-0.116*	-0.083*	-0.210*	-0.157***	0.159***	-0.090***	-0.181***
R&D	-0.086*	-0.084**	-0.014	-0.007	-0.051*	-0.026	-0.093**	0.271***	-0.008	-0.013
Social	-0.382**	-0.467***	-0.378***	-0.223	-0.270**	0.604*	-0.159	-0.239*	-0.033	-0.143
Environment	-0.224***	-0.136**	-0.106*	-0.058	-0.147***	-0.746***	-0.224***	-0.076	-0.064*	0.211***
Agriculture	-0.109	-0.220***	-0.104	-0.188*	-0.229***	-0.658***	-0.448***	-0.228***	-0.121***	-0.211***
Pop. Density	-0.046**	-0.017	-0.042***	-0.018	-0.021	0.042	-0.009	0.003	-0.011	-0.020*
GDP capita	0.072	0.005	-0.056	0.070	-0.011	-0.314**	-0.037	-0.027	0.015	-0.035
Agri. GVA %	0.003	0.002	-0.047*	0.044	-0.009	-0.043	-0.016	-0.001	0.008	0.021
Manuf. GVA %	-0.032	-0.033	-0.018	-0.067*	-0.030	0.013	-0.043*	-0.079***	-0.047***	-0.033*
Cpu density	-3.766***	-2.790***	-2.912***	-2.050*	-1.790*	-1.875	-4.218***	-1.799*	-1.923***	0.059
Tourists	0.830	1.370**	0.872	1.940**	-0.038	1.441	1.112*	0.211	0.505	0.784*
Gov. Vote %	0.009	-0.016	-0.017	-0.020	-0.013	-0.105***	-0.051***	-0.002	-0.014**	-0.005
Seat. Diff.	0.023	-0.001	0.132**	0.084	0.001	0.461***	0.072	0.007	0.014	-0.012
Pol. Cycle	0.053	-0.038	0.003	-0.048	-0.038	-0.274**	0.130**	-0.161***	-0.132***	0.065*
Year effect	0.006	0.006	-0.085**	-0.040	-0.034	0.048	0.142***	-0.078*	-0.159***	0.041
Constant	8.573***	6.428***	11.449***	2.814	5.535***	8.389	10.848***	2.679	6.733***	2.944*
Adj. R^2	55.903	73.413	57.446	47.955	55.536	39.205	51.571	62.198	70.795	50.039
Wald (overall)	564.26 (0.000)	1007.51 (0.000)	439.78 (0.000)	370.51 (0.000)	251.80 (0.000)	222.78 (0.000)	292.61 (0.000)	619.42 (0.000)	358.02 (0.000)	291.79 (0.000)
Wald (FE)	94.53 (0.000)	225.83 (0.000)	90.36 (0.000)	126.36 (0.000)	71.04 (0.021)	89.07 (0.000)	111.19 (0.000)	213.84 (0.000)	109.56 (0.000)	106.24 (0.000)

Note: (***) indicates p-value<0.01, (**) indicates 0.01<p-value<0.05, (*) indicates 0.05<p-value<0.1

Table 7. Results of the inter-sectoral investment competition model (with social investment as the numeraire variable)

	Road	*Rail*	*Air*	*Sea*	*Urban*	*Energy*	*ICT*	*R&D*	*Environment*	*Agriculture*
Road	0.387***	0.002	-0.013	0.144**	-0.028	-0.407***	-0.277***	-0.097*	-0.034	0.033
Rail	-0.019	0.299***	0.023	-0.013	0.056*	-0.229**	-0.067*	0.005	-0.006	0.071***
Air	0.012	-0.014	0.310***	-0.039	-0.030	-0.321**	-0.037	-0.108**	0.009	-0.005
Sea	-0.158***	-0.012	0.095**	0.159***	-0.038	0.017	-0.060*	0.064*	0.003	0.047*
Urban	0.027	-0.079	-0.054	0.164*	0.050	-0.032	0.039	0.001	0.011	0.131***
Energy	0.048**	0.014**	0.024	0.030	0.024*	0.126**	0.019	-0.020	0.002	0.020*
ICT	0.081	0.059	0.045	-0.026	0.007	-0.120	-0.067	0.249***	-0.091***	0.090***
R&D	-0.079*	-0.076**	-0.006	0.001	-0.043	-0.018	-0.085***	0.279***	-0.005	0.008
Social	-0.349**	-0.434***	-0.345***	-0.190	-0.237**	0.637*	-0.126	-0.206*	-0.110	0.033
Environment	-0.160**	-0.072*	-0.042	0.006	-0.083*	-0.682***	-0.160***	-0.012	0.275***	0.064*
Agriculture	0.012	-0.100*	0.017	-0.067	-0.108*	-0.538***	-0.327***	-0.108*	-0.090*	0.121***
Pop. Density	-0.035*	-0.006	-0.031**	-0.007	-0.010	0.053	0.003	0.014	-0.009	0.011
GDP capita	0.057	-0.010	-0.071*	0.054	-0.026	-0.329**	-0.052	-0.042	-0.050*	-0.015
Agri. GVA %	-0.005	-0.006	-0.055**	0.036	-0.017	-0.051	-0.024	-0.009	0.013	-0.008
Manuf. GVA %	0.015	0.013	0.029	-0.021	0.017	0.060	0.004	-0.033	0.014	0.047***
Cpu density	-1.842*	-0.867	-0.989	-0.127	0.133	0.048	-2.295**	0.124	1.982***	1.923***
Tourists	0.325	0.864*	0.367	1.440*	-0.543	0.937	0.603	-0.294	0.279	-0.505
Gov. Vote %	0.023*	-0.002	-0.003	-0.005	0.001	-0.091***	-0.036***	0.013	0.009	0.014**
Seat. Diff.	0.001	-0.014	0.118**	0.070	-0.013	0.447***	0.058	-0.006	-0.026	-0.014
Pol. Cycle	0.184***	0.094**	0.135***	0.083	0.094**	-0.142	0.262***	-0.029	0.196***	0.132***
Year effect	0.164***	0.165***	0.074*	0.119**	0.125***	0.207*	0.301***	0.080**	0.200***	0.159***
Constant	1.840	-0.305	4.715**	-3.919	-1.198	1.657	4.115**	-4.054*	-3.789**	-6.733***
R^2 (%)	58.896	75.110	55.491	45.804	37.017	31.021	46.835	63.903	64.923	70.795
Wald (overall)	649.15 (0.000)	1210.85 (0.000)	556.68 (0.000)	342.63 (0.000)	191.39 (0.000)	202.26 (0.000)	239.51 (0.000)	666.01 (0.000)	366.22 (0.000)	358.02 (0.000)
Wald (FE)	79.24 (0.005)	251.89 (0.000)	79.66 (0.004)	97.68 (0.000)	58.35 (0.169)	83.98 (0.001)	89.61 (0.000)	204.40 (0.000)	69.82 (0.027)	109.56 (0.000)

Note: (***) indicates p-value<0.01, (**) indicates 0.01<p-value<0.05, (*) indicates 0.05<p-value<0.1

Table 8. Summary of results of the inter-sectoral investment competition model

	Road	*Rail*	*Air*	*Sea*	*Urban*	*Energy*	*ICT*	*R&D*	*Social*	*Envi*	*Agri*
Road	**C**			**C**		**S**	**S**	**S**		**S**	
Rail	**S**	**C**			**C**	**S**	**S**	**S**	**S**	**S**	**C**
Air			**C**			**S**		**S**			
Sea	**S**		**C**	**C**	**S**		**S**	**C**	**S**		**C**
Urban		**S**	**S**	**C**				**S**	**S**	**S**	**C**
Energy	**C**	**C**			**C**	**C**		**S**	**S**		**C**
ICT				**S**	**S**	**S**	**S**	**C**	**S**	**S**	**C**
R&D	**S**	**S**			**S**		**S**	**C**			
Social	**S**	**S**	**S**		**S**	**C**		**S**			
Environment	**S**	**S**	**S**		**S**	**S**	**S**		**S**	**C**	**C**
Agriculture		**S**		**S**	**S**	**S**	**S**	**S**	**S**	**S**	**C**

Note: (C) indicates complementarity and (S) indicates substitution.

The negative budget spillovers may also be ascribed to different forms of substitutability among infrastructure systems, encompassing physical and functional interdependencies as well as regulatory and market interactions. In particular, the negative relationships among the ICT and transport expenditure categories can be explained by the limited interconnectivity and combined use (e.g., through Intelligent Transport Systems) of these infrastructures in the periphery, as they are principally confined across the country's development axis between Patra, Athens and Thessaloniki (Tsekeris et al., 2013). Additionally, the competitive conditions among most expenditure categories can be justified – to some extent – by the fact that, during the study period, the majority of public investments focused on the development of new infrastructure rather than maintaining and operating the existing one. Especially, as stressed in (Combes and Linnemer, 2000), new transport infrastructures are likely to compete with old ones and induce additional costs when they have to be integrated with the existing networks.

Regarding the role of control factors on the relative expenditure growth shares, the negative impact of agglomeration (density) and level of development (per-capita GDP) on investments related to road and air transport and the environment implies a policy focus on equity rather than on efficiency. Namely, such investment programs are mostly favoring the less developed and less urbanized regions with relatively poor accessibility, which is consistent with the EU cohesion policy objectives. The statistically significant negative effects of the agricultural GVA share (on air transport expenditure) and manufacturing GVA share (mainly on non-transport expenditure) stress the positive impact of the growing service sectors on the public investment activity in the country. Moreover, congestion (in terms of cpu density) is found to generally have a significant adverse (de-investment) impact on the relative growth shares of public spending in productive infrastructure networks, such as those of transport and ICT. This impact becomes statistically significant positive on the social and environmental spending (based on the model with social expenditure as the numeraire in Table 7). As it was expected, tourist arrivals have a statistically significant positive impact on the relative public spending for rail and maritime transport, ICT and the environment.

Finally, the results generally denote the statistically significant - although diverse among categories - effects of political factors on the sectoral allocation dynamics of regional public investments. This is in accordance with other studies in the literature of the political economy of infrastructure spending (e.g., Castells and Solé-Ollé, 2005; Flyvbjerg, 2009; Albalate et al., 2012). Particularly, public investments in energy, ICT and social infrastructure and services are found to relatively increase in those regions that voted against the government in the preceding election (‘swing-vote’ behavior). On the contrary, a “pork-barrel” strategy that fosters public investments in those regions with higher vote shares for the government party is found to be followed in the road transport and agri-food sectors (Table 7). The results also demonstrate that the positive impact of electoral competition, in terms of the difference in MP seats, is limited, as it is statistically significant only for air transport and energy expenditures. The impact of electoral cycle is found to be statistically significant and positive for the transport expenditure categories (except for maritime transport) (Table 7). This effect is generally significant although mixed on the various non-transport expenditure categories: positive for ICT, environment and agri-food sector spending, and negative for energy, R&D and social spending.

6. Conclusions

The measurement of interdependencies among public investments can offer valuable information for the on-going and ex-post evaluation of regional infrastructure projects funded by national and international (EU) funds. The proposed model demonstrated the highly competitive structure of public investment activity among different economic sectors across the Greek prefectures. The results showed that the underlying policy-making framework has generally failed to identify and address conflicting interests both within and between sectors. The findings verify those of Monastiriotis and Psycharis (2012) that Greece has used its public resources less than optimally, with an unsystematic manner, due to the inability to exploit sectoral complementarities and the lack of a clearly identifiable allocation strategy for public investments. This failure can possibly lead to severe inconsistencies and systematic inefficiencies in the composition of public investment programs, which potentially affect the economic viability and performance of multiple infrastructure systems. Such inefficiencies relate to adverse external effects, which arise when a region unilaterally, without a certain nation-wide strategy and coordinated way, over-provides public capital inputs of specific categories against others. Alternatively, the adverse effects can arguably denote that the capital produced in a sector cannot reduce the costs of production and transactions and increase the productivity of other sectors through complementarity.

The few synergistic effects are mainly focused on some productive network infrastructures, such as from maritime to air transport, from energy to road, rail and urban public transport, from road and urban public transport to maritime transport, and from maritime transport and ICT to R&D expenditures. Such types of infrastructure can be prioritized and funded through a stimulus spending package to help to attract more cross-industry investments, so that promote agglomeration economies and simulate the peripheral economy during the present downturn. The *a priori* imposition of a fixed budget constraint into specific sectors of the economy can prevent negative budget spillovers to other sectors and strengthen complementarities between certain types of investments. In particular, increased relative growth shares of maritime transport expenditure in the presence of budget constraint into the total transport sector can stimulate the investment activity in other non-road transport sub-sectors.

Investment determinants such as population density, per-capita GDP, the structure of economic production and geographical and political factors have a considerably heterogeneous impact on distinct types of transport and non-transport expenditure categories. Therefore, the regional allocation of public investments among the various sectors of the Greek economy can be considered as the outcome of a multi-criteria process. This process significantly deviates from criteria of economic efficiency and, hence, it departs from the conventional considerations of cost-benefit analysis. Specifically, it embraces equity and political considerations, according to the timing, location and type of investment.

In the light of the new programming period 2014-2020, where budget constraints become even more severe and crucial, the findings suggest the formulation of a more consistent, transparent and coherent approach for the unified planning and appraisal of the wider, multi-sectoral impacts of public investments. This approach would involve the coordination, prioritization, regulation and subsidization of specific types of infrastructures with significant positive fiscal externalities. Future research directions will involve the connection of the identified intra- and inter-sectoral investment interdependencies with a macroeconomic model to determine their effect on regional and national output and other performance measures.

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Appendix A1

Let y_{mr}^{t} denote the share of public spending with regard to the total spending in all sectors M, for investment category (and corresponding sector) m at a specific region r and time t. The inter-sectoral distribution of the relative expenditure allocated to sector m (whose regional subscript is fixed and omitted below for brevity purposes) is written as $Y^{t} = \left[y_{1}^{t}, \ldots, y_{m}^{t}, \ldots, y_{M}^{t}\right]$, $m = 1, \ldots, M$, $t = 1, \ldots, T$. This relationship constitutes a discrete system of distributional dynamics among sectors, given as $y_{m}^{t+1} = \left[F_{m}\left(y^{t}\right) \Big/ \sum_{k=1}^{M} F_{k}\left(y^{t}\right)\right]$, $m, k = 1, \ldots, M$, $0 < y_{m}^{t} < 1$, $F_{m}\left(y^{t}\right) > 0$, and $\sum_{m} y_{m}^{t} = 1$. The function $F_{m}(.)$ denotes the sectoral and temporal comparative advantages of investing on sector m and time t. The measure of $F_{m}(.)$ for each sector m is typically expressed in terms of a numeraire (or reference) sector. Assuming a numeraire sector $m = 1$, then, the expenditure in sector $m \neq 1$ and time t can be expressed through function $G_{m}\left(y^{t}\right) = F_{m}\left(y^{t}\right) / F_{1}\left(y^{t}\right)$, $\forall\, m = 2, 3, \ldots, M$, as a system of equations where $y_{1}^{t+1} = 1 \Big/ 1 + \sum_{m=2}^{M} G_{m}\left(y^{t}\right)$, when $m = 1$, and $y_{m}^{t+1} = y_{1}^{t+1}\, G_{m}\left(y^{t}\right)$, when $m \neq 1$. The function $F_{m}(.)$ can take any arbitrary form as long as it satisfies the positive value property. A multiplicative specification of $G_{m}(y)$ is adopted here to yield relative expenditure elasticities, i.e., $G_{m}\left(y^{t}\right) = A_{m} \prod_{k} \left(y_{k}^{t}\right)^{a_{mk}}$, $m = 2, 3, \ldots, M$, $k = 1, \ldots, M$, where the coefficient $A_{m} > 0$ is a constant specific to each sector m and $a_{mk} = \partial \ln G_{m}\left(y^{t}\right) / \partial y_{k}^{t}$ are elasticity terms that indicate the percentage growth in share of category m relative to that of numeraire (category 1), with respect to a unit percentage change of expenditure in category k. This multiplicative specification yields a system of log-linear equations for sectors m, which is specified as $\ln y_{m}^{t+1} - \ln y_{1}^{t+1} = \ln A_{m} + \sum_{k=1}^{M} a_{mk} \ln y_{k}^{t}$. In equation (1) of Section 3, the above relationship is transformed to a system of panel data equations to account for time- and region-specific fixed effects. It is further augmented to consider the analysis of investment interdependencies among distinct groups of expenditure categories (for $M' < M$) and include the corresponding budget constraints.

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