Duality theory and cost function analysis in a regional context: the impact of public infrastructure capital in the Greek regions

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Abstract

The resurgent interest in the role of infrastructure on development, spurred by the work on Aschauer in the late eighties, has produced a voluminous research activity, both at national and regional levels. Even though the majority of this research is based on production function analysis, more recently has emerged the alternative analytical framework of duality theory and cost function analysis. The latter is utilised here, in an effort to investigate public capital's impact on manufacturing at the regional level (Greek prefectures). Public capital categories have been grouped to two major categories of 'productive' and 'social' infrastructure. The latter seems to play little role in reducing private costs, but the former appears to be an important cost reduction influence. It can also be demonstrated that infrastructure has a substitutional relationship with labour and intermediate inputs, and a complementary one with private capital.

1. Introduction

In the last decade or so interest in the effect of public infrastructure on national and regional economies has generated a voluminous literature. The renewed debate was sparked by the works of Ratner (1983), and especially Aschauer (1987; 1988; 1989a) about the way in which US public capital has affected development and productivity. Despite the fact that there are numerous examples of similar research, both from the United States and other countries, the term public infrastructure capital (here used interchangeably with the terms public capital, public infrastructure, or just infrastructure) remains problematic. It tends to have different meanings in different contexts as the introduction to definitional issues on infrastructure by Diamond and Spence (1989) indicates.

Most empirical work is based on a production function approach. This research has generated results which have both corroborated Aschauer's thesis that infrastructure plays a significantly positive role on the private sector's productivity (thereby advocating the extension of public investment programmes), and rejected it (proposing the extensive implementation of 'user fees' on infrastructure use). Section two of this paper provides a compendium of this theoretical debate, as well as the basic research findings to date. However, and more important, in the present context, it also introduces some examples of an alternative analytical framework - that of cost function analysis. The next section delineates, in detail, duality theory and cost function analysis. It also provides the theoretical tools, derived from this approach, by which the effects of public capital on the private sector can be measured. The paper then describes the Public Investment Programme (PIPR) which has been the main source for public infrastructure investment in Greece. Section five presents an empirical calibration within this particular theoretical framework and the results obtained for the secondary sector (manufacturing) at the prefectural level (EU regional level: NUTS III) in Greece between 1982 and 1991. The last part summarises the main findings of the analysis.

2. Infrastructure and the economic performance of the private sector: context.

Amongst the main questions in regional analysis are the determinants of regional growth and the role of the state in its promotion. One of the tools of regional development policy, either used implicitly or explicitly, is the public investment in infrastructure capital. The interest for the study of the public capital's impact on national and regional economies was intense after the Second World War given that the existing infrastructure was seriously damaged in many countries, and especially in Europe. This sparked a theoretical research debate that provided some serious insights for the mechanisms by which infrastructure affects development.

Even though the aforementioned research had shed some light into the links between infrastructure and development, serious obstacles, at both the theoretical and applied research level, have since remained for a fuller understanding of what has proved such a complex relationship. The mechanics of the links were (and still are to a certain degree) left still to be unveiled, and in many cases even the definition of 'public (infrastructure) capital' seemed problematic. But even if the theoretical and definitional problems were circumvented, it was difficult to measure with accuracy even the basic notion of the capacity of infrastructure at regional or national levels. It is worth mentioning at this point the work of the EU group of researchers, convened by Biehl, set up to evaluate the contribution of infrastructure to the development of European regions (Biehl 1986), which was one of the most serious attempts to address these issues at the sub-national level. This attempt was founded on the physical measurement of public capital's stock. However, despite the potential advantages of this approach, it is difficult (and costly) to construct such measures, and even more so to replicate such measurements frequently. An additional difficulty is the depiction of the qualitative characteristics of the existing stock. The alternative approach to infrastructure capacity measurement – that based on a monetary measure - assumed dominance during the resurgence of research into the role of public capital in the late eighties-early nineties.

The most notable example of the monetary approach was seen in the research of Aschauer (1987; 1988; 1989a). This work had such influence that it initiated a whole-renewed interest on the effects of the public infrastructure[i]. The research contained in these papers attempted to answer one of the great theoretical questions that had baffled economists and other scientists working at sub-national scales, which is why there had been a significant slowdown of the growth in US productivity. During the seventies there was an unprecedented decline of labour productivity growth, and even though there has been a slight recovery of this growth rate during the eighties, the fact remains that it is still significantly lower than the average for the post-war period. Several explanations have been proposed for the productivity growth slowdown, such as the energy crisis, changes in the nation's demographic characteristics and educational attainments of the labour force, the decrease in the rate of capital investment, and the sectoral shift away from manufacturing, etc[ii].

However, Aschauer attributed the productivity slowdown to the decline of the public infrastructure investment in the US. He introduced public capital into a Cobb-Douglas production function, along to the other factors of production process (labour and private capital). The overall conclusion was that the level of public capital provision significantly affects the productivity of the private sector in the world's leading economy (1989a, 1989c). He reached a similar conclusion using data for other major national economies (1989b). One salient feature of these studies is that while public investment has a positive association with productivity, other public spending - such as public consumption - has a negative one. He also argued that different categories of infrastructure have different impacts on the performance of the private sector. It is those categories that he classified as 'core' infrastructure (highways, airports, mass transit, electrical and gas facilities, water, sewers) that have the most fundamental impact (1989a).

The idea that infrastructure can have such an impact on the private sector productivity has generated a vigorous debate, and voluminous applied research. Munnell's (1990a) results supported Aschauer's thesis, even though in her research infrastructure seems to have had a more moderate causal effect. She also provided a regional dimension to the research on public capital for the US, where the overall influence of infrastructure provision remains the same (1990b). On the other hand, in a number of important papers Holtz-Eakin (1992, 1993a, 1993c) argued that the causation of the relationship between public capital and productivity is the reverse than that identified by Aschauer and Munnell. His view was that the post-war period of high productivity growth, which the American economy had experienced, resulted in an unprecedented economic growth, which in turn gave to the federal and state governments the fiscal ability to undertake substantial infrastructure projects. It was, he argued, the decline of productivity during the seventies that had, as a result, a budgetary constraint at all levels of government. As many of the consumption expenditures are inelastic, programmes of infrastructure investment were cut down or postponed. He also thinks that the same argument of reverse causation can be applied at the regional level. Holtz-Eakin dismissed Munnell's regional analysis arguing that it is the fiscal ability of 'richer' American states to undertake public investment that has endowed them with a better stock of infrastructure, and not the reverse (Holtz-Eakin 1993a).

There are numerous examples of subsequent similar research from the US, as well as from many other countries. Garcia-Mila and McGuire (1992), specifying a regional production function, at first supported Aschauer's argument. However, in a more recent paper, where more elaborate techniques were employed, they reject their initial results (Garcia-Mila et. al. 1996). The role of infrastructure is also insignificant according to Kelejian and Robinson (1994). It has to be noted that in their most recent work with even more elaborate econometric techniques, the spatial dimension of the data is examined exhaustively, and again concluding that model specification can play a crucial role as to the results obtained (1997). Tatom (1991, 1993) also supported the argument that rejects the positive role of infrastructure in productivity growth and Dalenberg and Partridge (1994) report similar conclusions. For the reverse argument, Pinnoi (1995), estimating a translog production function reached positive results for the role of infrastructure. The results reported from international comparisons regarding the role of public capital have also been inconclusive. Aschauer (1989b) found a positive effect, Ford and Poret (1991) reached ambiguous results, and Evans and Karras (1994) did not find any impact at all for infrastructure capital. Positive results, however, derive from Japanese research, as evidenced by the pioneering work of Mera (1975) and from the more recent research of Miyawaki and Tobita (1992), and Okhawara and Yamano (1997). Prud'homme (1996) also reported positive results for the French case and infrastructure seems to play a positive role also in Spain according to Cutanda and Paricio (1994), and Mas et. al. (1996). But the findings have been inconclusive for the Netherlands (Sturm and de Haan, 1995).

The production function analysis dominance of the infrastructure debate, however, is not uncontested. An alternative analytical framework is provided by the duality theory and cost function approach. In production function analysis, output is considered as endogenous, and the production inputs as exogenous. Cost function analysis is based on the dual cost function of the (primal) production function. This former embodies all the parameters of the latter, but with a crucial difference. In cost function analysis, it is input quantities and production costs which are endogenous, and the level of output and input prices that are exogenous. (For a concise historical presentation of the cost function approach see Berndt (1991) and for a more extended analysis see, for example, Diewert[iii] (1986) and Chambers (1988).

There is now, in existence, a substantial body of work on the effects of infrastructure using the cost function approach. In the US, Nadiri and Mamuneas (1994) using a panel of industrial sectors found that public capital had a positive impact on private sector productivity. Lynde and Richmond (1992, and 1993a) and Morrison and Schwartz (1992, and 1996) have also reported beneficial effects of the provision of US infrastructure. Similar research has been conducted in Europe. Berndt and Hansson (1991a) have investigated the Swedish case, Lynde and Richmond (1993b) looked at the UK, Conrad and Seitz (1994) provided a sectoral analysis for Germany, Seitz and Licht (1995) focused on a regional analysis for the (West) German states, and Seitz (1993 and 1994) analysed the effects of the total public capital and road infrastructure respectively. In all these cases, infrastructure capital appears to have, once again, a positive role regarding the private sector's costs and productivity.

3. From production functions to cost functions and duality theory.

The analytical framework of production functions can be extended with duality theory if it is assumed that firms in the private sector choose input quantities in such way that they minimize the cost of their production process, given the prices of these inputs. Let the production function be:

$$Y_i = f_i(L_i, K_i, M_i, G_i, t) \qquad (1)$$

where, Y_i is the output (value added) in sector i, L_i is the labour input, K_i is the private capital input, G_i is public capital input, and t is a time counter which functions as a proxy for disembodied technical change. The subscript i is a regional index.

Then the cost function of an industry in region i will be:

$$C_i = C_i(w_i, p_k, p_m, Y_i, G_i, t) \qquad (2)$$

where C_i is the private cost of production in sector i, w_i is the wage in sector i, p_k is the rental price of private capital, p_m is the price of intermediate inputs, and the others are as above.

Cost function (2) can be derived by minimising the private production cost function:

$$C_i = w_i L_i + p_k K_i + p_i M_i \qquad (3)$$

subject to the production function (1).

From cost equation (2) is possible to derive the cost minimising factor demand equations using Shephard's Lemma (see for instance Takayama (1985) or Chambers (1988)) for labour L^*_i, private capital K^*_i, and intermediate inputs M^*_i. These equations would be:

$$L_i^* = \partial C_i / \partial w_i \qquad (4)$$

$$K_i^* = \partial C_i / \partial p_k \qquad (5)$$

$$M_i^* = \partial C_i / \partial p_m \qquad (6)$$

The private costs of production for the optimising firms, using the left-hand side of equations (4)-(6), would be:

$$C_i = w_i L_i^* + p_k K_i^* + p_m M_i^* \qquad (7a)$$

or, using the right hand sides, which is the application of Shephard's lemma, of equations (4)-(6), the equivalent expression would be:

$$\frac{\partial C_i}{\partial G_i} = -w_i \frac{\partial L_i^*}{\partial G_i^*} - p_k \frac{\partial K_i^*}{\partial G_i^*} - p_m \frac{\partial M_i^*}{\partial G_i} \text{ or}$$

$$\frac{\partial C_i}{\partial G_i} = -w\varepsilon_{Li} - p_k\varepsilon_{Ki} - p_m\varepsilon_{Mi} \qquad (7b)$$

$$= s_{Li} + s_{Ki} + s_{Mi} = -s_{Gi} \qquad (7c)$$

A measure of the impact of public capital on private cost is the cost elasticity with respect to public infrastructure (ε_{CG}). This elasticity can be construed as the degree of how much infrastructure capital will reduce the costs of industries operating in the region. More formally, ε_{CG} is the percentage change of the private cost of production as a result of a unitary change in the public capital stock, *ceteris paribus*. The elasticity ε_{CG} would be:

$$\varepsilon_{CGi} = -\frac{\frac{\partial C_i}{C_i}}{\frac{\partial G_i}{G_i}} = -\frac{\frac{\partial C_i}{\partial G_i}}{\frac{C_i}{G_i}} \qquad (8)$$

Closely linked with cost elasticity with respect to public infrastructure (ε_{CG}) is the concept of the 'shadow value' of public capital. As the flow of services from public capital can be considered as a free public good, there is no market price for these services[iv]. Nevertheless, it is possible to have an estimate of their shadow value[v] (s_{Gi}). The shadow value of public capital is a measure of the impact on private cost of an exogenous change in the level of services delivered by public capital, *ceteris paribus*. It shows private sector willingness to pay in order to obtain an additional unit of service from public capital. This shadow value of public capital would be:

$$s_{Gi} = -\frac{\partial C_i(w_i, p_k, p_m, Y_i, G, t)}{\partial G} \qquad (9)$$

If there is such an exogenous increase in infrastructure services, it is expected that there will be a corresponding increase in private sector productivity ($\partial Y_i / \partial G_i \geq 0$). The value ε_{CG} is directly linked with the shadow value s_{Gi}. Expression (8) can be derived by (9) and the reverse:

$$\varepsilon_{CGi} = s_{Gi}\frac{G_i}{C_i} \quad \text{or}$$

$$s_{Gi} = \varepsilon_{CGi}\frac{C_i}{G_i} \qquad (10)$$

It is also possible to have a measure of infrastructure's impact on the private input shares (labour, private capital, or intermediate input) to production. If an increase (or decrease, or no change) of the stock of public capital has an effect of an increase (or decrease, or no change) of a private factor of production, then it can be argued that infrastructure is using this input (or saving it or has a neutral effect, respectively). A measure of the this cost share change is the 'factor bias effect' (see Nadiri and Mamuneas, 1994), and the respective effects in the case of three private inputs would be:

for labour,

$$bias_{LG} = \frac{\partial S_L}{\partial \ln G} \qquad (11)$$

for private capital,

$$bias_{KG} = \frac{\partial S_K}{\partial \ln G} \qquad (12)$$

and for intermediate inputs,

$$bias_{MG} = \frac{\partial S_M}{\partial \ln G} \qquad (13)$$

The total infrastructure effect on the demand for private inputs can be estimated using private input elasticities with respect to public infrastructure (ε_{XG}), where X = L, K, M. These elasticities would be:

$$\varepsilon_{XG_i} = \frac{\dfrac{\partial Q_X}{Q_X}}{\dfrac{\partial G_i}{G_i}} = \frac{\partial \ln Q_X}{\partial \ln G_i} \qquad \text{(where } Q_X \text{ = the quantity of inputs L, K, M)} \qquad (14)$$

In an applied research context, these elasticities can be estimated directly from the respective cost elasticities, and the factor bias effect over share, as private input elasticities are the sum of these former measures. Put differently, the total impact of public capital on input demand (ε_{XG}) is the sum of the productivity effect (cost elasticities) and factor bias effect. If a private input elasticity, with respect to public infrastructure (ε_{XG}), has a positive sign (or negative, or zero), then public infrastructure has a complementary (or substitutive, or neutral) relationship with the respective private input component.

4. Public infrastructure capital in the regions of Greece.

The Public Investment Programme (PIPR) has been the primary channel of public investment in Greece since 1952. The PIPR has financed the great bulk of infrastructure projects both at the national and the regional level. Sub-national data are available from 1976 onwards.

The PIPR comprises by several categories of public investment according to end use, for example related to industry, transportation, education, health, water supply, etc. For analytical reasons these categories have been grouped into three major headings. One such group is made up of those categories that in infrastructure research are usually classified as 'productive' public capital[vi]. These are the Agriculture, Forestry and Fishery, Industry, Energy and Handicrafts, Irrigation, Research and Technology, Special Works (plus those of Athens/Thessaloniki), Transportation (plus those for Railways), Water/Sewage Works, and Prefectural Works/Programmes categories of the PIPR. A second group includes those categories which usually would be classified as 'social' infrastructure, such as Education, Health and Welfare, Housing, Public Administration, and Tourism. The last group is those categories that are, in reality, operational expenditures of the PIPR, and are not materialised as 'real' public investment. These categories have been excluded from the subsequent analysis. In 1992 the productive category's share of total expenditure was around 78 percent, the social component made up a further 17 percent, and the remaining 5 percent comprises miscellaneous and administrative expenditures categories.

An interesting feature of the evolution of infrastructure expenditure is the fact that during the late-seventies and early-eighties the real investment part of PIPR decreased from its. However, this tendency was reversed during the eighties, and the total real investment expenditure of the programme increased to return to the mid-seventies level.

The greatest part of PIPR is allocated regionally at the prefectural level (NUTS III level according to the EU classification). However, another part of PIPR investment is directed to inter-prefectural projects (NUTS II level) and these investment projects have not been included in this analysis In this sense, the infrastructure stocks used here underestimate the real public capital stock. The public capital stocks were estimated using the perpetual inventory method:

$$G_t = (1-\delta)G_{t-1} + I_t \quad (15)$$

where G_t is the end-of-year public capital stock in year t, δ is the geometric rate of depreciation, and I_t is real investment in public capital during years t. For more details on the method see for example Holtz-Eakin, (1993b)[vii].

The data for the private sector refer to 'large scale' manufacturing. These data are the only available at the prefectural level supplied by the Statistical Service of Greece[viii]. Large scale manufacturing in the Greek context is any industry that employs twenty or more persons. This scale of manufacturing amount to almost 90 percent of the total secondary sector in Greece. The private capital stocks were constructed in the same way as their public sector counterparts. These private stocks are used here as a proxy for the quantity (K) of private capital input

It is helpful to understand as context that during the eighties industry in Greece had to confront a deep crisis. This can be seen in the persistent decline of average annual employment since 1986. But probably the most salient feature of the crisis was the huge decline in levels of private investment. By the late eighties, gross asset formation in manufacturing has lost around one fourth of the levels reached in the mid-seventies. This is all in complete contrast to an opposite trend ongoing in public capital investment, in which the real part of the PIPR spend has stayed stable or has been modestly increased during the same period

5. Estimation of regional infrastructure cost functions in Greece.

There are several empirical forms that the general cost function can take. According to Berndt (1991) in his review of the history of the development of such functional forms, it was Diewert who first introduced the generalised Leontief form, which is used in infrastructure research by Berndt and Hansson (1991) for Sweden and Seitz (1993;1994) for Germany. An alternative form is the translog cost function, used by Conrad and Seitz (1994), and Seitz and Licht (1995) for sectoral and regional analyses of the role of German public capital respectively. Another potential empirical form for the cost function is that used by Nadiri and Mamuneas (1994) in their analysis of the effects of public infrastructure on US manufacturing. This exact form has been used in part in the subsequent analysis as a full translog calibration and it has to be reported that it generates rather poor results (insignificant *t*-ratios for some of the estimated variables), even without the introduction of public capital into the equation. There will be more on the alternative specifications later.

The cost function used here, has the following form:

$$\ln\frac{C_i}{p_m} = \sum_{i=1}^{n}\alpha_{0,i}D_i + \sum_{i=1}^{n}\alpha_{L,i}\ln\left(\frac{w_i}{p_m}\right)D_i + \sum_{i=1}^{n}\alpha_{K,i}\ln\left(\frac{p_k}{p_m}\right)*D_i + \alpha_Y\ln Y + \alpha_G\ln G + \alpha_T t$$
$$+\beta_{LK}\ln\left(\frac{w_i}{p_m}\right)\ln\left(\frac{p_k}{p_m}\right) + \beta_{LY}\ln\left(\frac{w_i}{p_m}\right)\ln Y + \beta_{LG}\ln\left(\frac{w_i}{p_m}\right)\ln G + \beta_{LT}\ln\left(\frac{w_i}{p_m}\right)t$$
$$+\beta_{KY}\ln\left(\frac{p_k}{p_m}\right)\ln Y + \beta_{KG}\ln\left(\frac{p_k}{p_m}\right)\ln G + \beta_{KT}\ln\left(\frac{p_k}{p_m}\right)*t + \beta_{YT}\ln Yt + u_C \qquad (16)$$

(for definitions, see section 3)

The respective cost share equations then would be:

for the labour input,

$$s_L = \frac{wL^*}{C} = \sum_{i=1}^{n}\alpha_{L,i}D_i + \beta_{LK}\ln\left(\frac{p_k}{p_m}\right) + \beta_{LY}\ln Y + \beta_{LG}\ln G + \beta_{LT}t + u_L \qquad (17)$$

and for private capital input,

$$s_K = \frac{p_k K^*}{C} = \sum_{i=1}^{n}\alpha_{K,i}D_i + \beta_{LK}\ln\left(\frac{w_i}{p_m}\right) + \beta_{KY}\ln Y + \beta_{KG}\ln G + \beta_{KT}t + u_K \qquad (18)$$

It is also possible to have a third share equation - that for intermediate inputs (s_M). However, as the cost shares add to unity ($s_L + s_K + s_M = 1$), it is necessary to exclude one of the cost share equations, because otherwise the system of equations would be singular[ix]. The system of equations that is estimated comprises the set (16)-(18)[x] This is the homogeneity restriction for the estimated system. An additional set of restrictions, regarding symmetry conditions across equations (16)-(18), has also been imposed. For instance, the coefficient β_{KL} obtained by the cost share equation (17) has been constrained to be equal to coefficient β_{KL} obtained by the cost share equation (18), and to β_{LK} obtained by the cost function (16). The parameters for the excluded equation, dealing with the cost share of intermediate inputs, can be derived from the estimated parameters of the cost equation and the labour and private capital share equations, given the aforementioned restrictions.

It is assumed that the error terms in equations (16)-(18) (u_C, u_L, and u_K respectively) are jointly normally distributed with zero expected value, and also that the covariance matrix is positive definite symmetric. The estimation method selected is that of iterative seemingly unrelated regression (SUR)[xi]. It has also to be noted that the parameter estimates obtained with the SUR method are „numerically equivalent to those of the maximum likelihood estimator" (see Berndt 1991, p. 463).

As the analysis is based on a panel of regional data, the estimated set of equations has to be calibrated in such a way that ensures that the specific nature of the dataset has been taken into consideration. Thus, every equation of the system (16)-(18) has been appended with a set of regional-specific dummies D_i (where i is a regional indicator, and the regional dummy is equal to one in region i, and zero in all other regions). Such a formulation is necessary in order to capture the regionally specific characteristics (see, for instance, Hsiao 1986, or Baltagi 1995). One component of the infrastructure research literature, where comparable datasets have been employed for the estimation of similar sets of equations, extended the use of dummy variables such as these to the cases of $\alpha_{L,i}$, and $\alpha_{K,i}$ coefficients (see Nadiri and Mamuneas, 1994; Seitz, 1993, 1994; Seitz and Licht, 1995). Such a formulation has also been followed here, as it ensures that the labour and private capital demand equations can be consistently derived by the cost equation.

Even though a cost equation similar in form to that of Nadiri and Mamuneas (1994) is used here, there is one significant difference. Here there is no a priori assumption that there are constant returns of scale (CRS). In contrast to the Nadiri and Mamuneas approach, a CRS variant is compared to a version without such a restriction. Such a comparison has been proposed and tested by Seitz (1994) and, in a regional context, by Seitz and Licht (1995). In order to compare the two versions, with and without the CRS restriction, a log-likelihood ratio test (LRT) has been used. The LRT is a rather simple test, which can be briefly described as follows: if the values of the maximised log-likelihood functions are lnL_r for the restricted, and lnL_u for the unrestricted model, then the likelihood ratio statistic is given by:

$$\lambda = -2(\ln L_r - \ln L_u) \qquad (19)$$

This statistic is asymptotically distributed as chi-squared, and the degrees of freedom are equal to the imposed number of restrictions[xii]. The LRT has been also used here to compare the unrestricted model with regional dummy variables to an alternative specification where such variables have been excluded. Following Seitz (1994) and Seitz and Licht (1995), the log-likelihood ratio test has also been utilised in order to discern if the public capital variable should be included in the estimated equations or not. Again, the unrestricted model is the one with the inclusion of infrastructure, and the restricted the version is without public capital.

The dataset used in this analysis is a panel with a time dimension from 1982 to 1991, and a cross-sectional vector of 49 prefectures. There are 51 prefectures in the Greek administrative and statistical system (the semi-autonomous prefecture of Agion Oros is not counted). However in Lefkada, based on unpublished data provided by the Statistical Service of Greece, there was, in fact, no industrial activity at the scale analysed here during the period. Also in Kephalonia industrial activity of this scale only commenced in 1984 and for this reason the figures for both public investment and private sector characteristics were added to the adjacent prefecture of Zakynthos. Hence, the number of prefectures in the analysis is reduced from fifty-one to forty-nine.

The economic variables that enter the cost function representing the private sector have been constructed as follows. The quantity of labour (L) is the total working hours in manufacturing in prefecture i. Total working hours, in turn, were estimated by multiplying the average annual employment in the manufacturing industry by the number of hours worked [xiii]. The price of the labour input (w_i) has been calculated by dividing the total remuneration[xiv] of labour input in prefectural industry i by the quantity of labour input (L). It has to be noted that w_i enters the system of equations normalised to equal one for the first year of the panel.

Private capital stocks for prefectural manufacturing have been used as a proxy for the quantity of private capital input (K). The estimation method is again via the method of perpetual inventory accounting:

$$K_{it} = (1-\delta_p)K_{it-1} + IP_{it} \qquad (20)$$

where, K_{it} is the end-of-year private capital stock in year t in prefecture i, δ_p is the geometric rate of depreciation, and IP_{it} is real investment in private capital during years t in prefecture i. Even though there is not a price for private capital, in the sense that a price can be defined for the labour or intermediate inputs, a user cost of capital p_K can be calculated as follows:

$$p_K = (r+\delta_p)q_K \qquad (21)$$

where, δ_p is as in equation (20), r is the long-term lending rate for the industrial sector (nominal, referring to loans for more than a year), and q_K is the investment deflator for capital goods[xv]. This capital goods investment deflator is a weighted measure of the national price indexes of building and equipment investment in manufacturing[xvi]. The price of private capital (p_K) has been normalised to be equal to one for the first year of the panel -1982.

The quantity of intermediate inputs M is the sum of materials, energy, and services that were consumed during the production process, divided by the price index of intermediate inputs (p_m). This index is a weighted average of the raw materials and semi-finished products index, and fuel and lubricant index (again obtained from the Statistical Service of Greece). The price index of intermediate inputs is also normalised to be equal to one for the first year of the panel.

Output quantity is estimated as the total value of gross regional manufacturing output divided by the output price index. This is the final products index as provided by the Statistical Service of Greece, normalised here to be equal to one for 1982.

The cost variable (*C*) is the sum of the cost of the labour input $(L * w_i)$, private capital input $(K * p_k)$, and intermediate inputs $(M * p_m)$. The value S_L is the percentage of the labour input to the total cost, while S_K is the percentage of private capital, and the S_M the percentage of intermediate inputs.

As it is mentioned earlier, the estimation model consists of the cost equation (16), and the share equations (17) and (18), for labour and private capital inputs, respectively. Table 1 presents the results from the estimation of the system of equations, where productive public capital has been included[xvii], as well as the test statistics from the comparison of this specification to alternative formulations.

The 'fitness' measures appear to be satisfactory, either in terms of explained variance or standard errors, for the equations of the system. However, the coefficients for a_G, b_{LK}, b_{LT}, b_{KT}, and b_{YT} appear not to be statistically significant. The last part of table 1 gives the results from the comparisons of the formulation with public infrastructure, fixed effects, and without the restriction of constant returns to scale, to alternative formulations. The comparison with a specification without fixed effects (region-specific dummy variables) gives a value for LRT_D as 2,076.86 (with 147 degrees of freedom). For the formulation where public infrastructure has been excluded LRT_G is 76.02 (with 3 degrees of freedom), and for the alternative where the assumption of constant returns to scale is imposed LRT_Y is 137.26 (with 4 degrees of freedom). In all cases the alternative specifications have been rejected decisively (the associated probability value is 0.000).

It has to be mentioned that a similar analysis was conducted to generate results for the social category of public capital. Again the formulation with social infrastructure and regional fixed effects (the unrestricted model) was tested against a formulation with public capital but without fixed effects (LRT_D), one with fixed effects but no public capital (LRT_G), and one similar to the unrestricted version but with no constant returns to scale imposed (LRT_Y). The assumption that social public capital is a part of the estimated system has to be rejected in favour of the alternative hypothesis (LRT_G = 4.72 , with 3 degrees of freedom). For this reason all of the subsequent analysis presented here refers only to productive public capital (henceforth just public capital).

As mentioned earlier, the effect of public capital on regional manufacturing can be estimated using the cost elasticity with respect to public infrastructure (ε_{CG}). The results for the different prefectures of the analysis are presented in table 3. In all cases the sign of the prefectural cost elasticity is negative, which means that infrastructure tends to reduce the manufacturing costs in all cases. However, this cost reduction seems rather small and certainly is without significant regional variation. The highest cost elasticity is that of Zakynthos-Kephalonia (-0.071), followed by Ioannina (-0.066). Low values area recorded for Chios (with -0.059), and Evros, Kozani, and Serres (-0.058). It is somewhat disappointing to discern no clear pattern in these elasticities. It is also difficult to compare these results to the findings of other research, as there are few similar analyses at the regional level. In the research conducted by Seitz and Licht (1995), the 11 (West) Germany states (Bundesländer) are far larger than the Greek prefectures. (Bavaria is not much smaller than Greece as a whole, both in geographical and economic terms.) All German regions appear to have significantly larger cost elasticities, and for Berlin and Bremen alone are the figures similar to those of Greek prefectures. It has to be noted, however, that it is likely that the fact that the regional data refer only to aggregate manufacturing has played an important role Similar results obtained from a sectoral breakdown have given much higher cost elasticities for infrastructure in Greece at the national scale.

The effect of infrastructure on the cost shares of the production inputs is measured by the factor bias effects, which are equal to the coefficients of private inputs to public capital, β_{LG} and β_{KG} respectively for labour and capital, plus the derived coefficient β_{MG} for intermediate inputs. Table 4 presents these effects divided by the corresponding private input share, following the form of presentation favoured by Nadiri and Mamuneas (1994). The overall result from a first look at these figures is that for all prefectures public capital appears to be labour and intermediate inputs saving, and private capital using. The first column of table 4 (biasLG) gives the estimations[xviii] for labour input. The highest values (that is the greatest cost reduction) appear to be in Korinthia (biasLG = -0.589), Lasithi (-0.482), and Laconia (-0.370). The lowest values are those for Kyklades (-0.051), Grevena (-0.096), and Drama (-0.100). There is no discernible spatial pattern in these figures. The fact that the regional manufacturing under examination is the sum of all manufacturing sectors may, in part, be contributory factor in this respect. Certainly it is not difficult to argue from a theoretical standpoint that sectoral composition should a significant role, as some industrial sectors are expected to be more affected by changes in infrastructure stock levels tan others.

The results for private capital bias (KG) are all positive, which can be interpreted as public capital being private capital using. However, here the variation amongst prefectures is greater, in magnitude terms, than in the case of labour input. The highest factor bias effects for private capital can be found in Lasithi (biasKG = 2.217), which has one of the highest values for labour input. The next highest bias effect for private capital is that of Kastoria, which in contrast is one of the lowest cases for labour. Other prefectures with high bias effects for private capital are Fokida (1.391) and Evritania (1.005). The lowest values can be found in Samos (0.250), Viotia (0.215), and Kozani (0.196). The last column of table 4 presents the factor bias effects for intermediate inputs (biasMG). The sign for all prefectures is negative, which means that public infrastructure is intermediate inputs saving. The highest savings can be found in Thesprotia (biasMG = -0.416), Kozani (-0.335) - which has one of the lowest effects for capital, and Grevena (-0.313). The lowest values are observed in Chania, Korinthia (biasMG = -0.113 for both regions), Karditsa (-0.111) and Fokida (-0.110).

The cost elasticity with respect to public capital can be considered the ‘productivity’ effect of infrastructure and, if this measure is combined with the factor bias effect, the total effect of infrastructure on private inputs can be obtained. This measure (table 5), as indicated in section 3, is the private input elasticity with respect to public infrastructure. There is, of course, the possibility that the two components of these elasticities - the productivity and the factor bias effects - could offset each other, in terms of magnitude and sign. But for the Greek prefectures, all private input elasticities have the same sign as the respective factor bias effects. A comparison of these figures to those of table 4 shows that the demand elasticities are determined, at least in most cases, by the factor bias effects, as the magnitude of cost elasticities with respect to public capital are rather small. Thus, the majority of those prefectures that have high (low) bias effects also have high (low) demand elasticities. All prefectures have a negative sign for labour and intermediate inputs cost elasticities (ε_{LG} and ε_{MG} respectively), and a positive sign for private capital (ε_{KG}). In economic terms this means that an expansion of the infrastructure stock results in a decline in the demand for labour and intermediate inputs, and an increase in the demand for private capital input.

The prefectures with the highest labour demand elasticity are Korinthia (ε_{LG} = -0.653), Lasithi (-0.544) and Laconia (-0.436). On the other hand, the lowest values are recorded for Drama (-0.163), Grevena (-0.159) and Kyklades (-0.115). The second column of table 5 presents the findings for private capital demand elasticity. Here, as for the bias effects for capital, there is a greater spatial variation in the elasticities compared to those for labour input. The largest elasticities were observed in Lasithi (ε_{KG} = 2.155), Kastoria (2.131 – which, in contrast, has a low labour elasticity) and Fokida (1.326). At the opposite extreme are prefectures such as Samos (0.185), Grevena (0.174 - which also has one of the lowest elasticities for labour), Viotia (0.154) and Kozani (0.138). Finally, table 5 offers the demand elasticities for intermediate inputs where the highest are observed in Thesprotia (-0.479), Kozani (-0.393), Grevena (-0.376) and Kyklades (-0.341). Prefectures with low demand elasticities for intermediate inputs are Korinthia (-0.178), Fokida (-0.175), Karditsa (-0.173) and Lasithi (-0.162).

The private input elasticities with respect to public infrastructure obtained from this analysis can be compared to those obtained from similar research. Seitz and Licht (1995) have found that private capital (which they divide into two categories) has a complementary relationship with public infrastructure, while labour is substitutive. This is also the case in this paper. Similar relationships have been identified for Sweden by Berndt and Hansson (1991). Nadiri and Mamuneas (1994), on the other hand, find that although infrastructure has a substitutive effect for labour, in their research private capital also appears to have a substitutive relationship with public capital, while intermediate inputs are complementary.

The final results describe the estimations of the shadow values (s_{Gi}) for infrastructure capital in the different prefectures. Thus, table 6 shows the differences in the degree that regional manufacturing is willing to pay in order to have an additional unit of public capital. Here, in contrast to the other measures of the impact of infrastructure, it looks as if a clear regional pattern emerges. There is a substantial variation in these shadow values and it seems that those prefectures that are adjacent to the two main metropolitan areas - Athens and Thessaloniki - have the highest shadow values. The only prefecture that is not adjacent to a principal economic centre and has a high value is Magnesia and this contains the significant industrial area of Volos.

6. Conclusions.

This paper presents an attempt to apply duality theory to the analysis of the impact of public infrastructure spending on Greek manufacturing at the regional level. To undertake this task a cost function has been specified and a panel of regional data for public capital and the private sector employed. This simple cost function is similar to that used by Nadiri and Mamuneas (1994) for the analysis of US manufacturing sectors, although these authors assume that there are constant returns to scale. This assumption was tested and rejected here for the case of productive public capital. Two alternative formulations were also tested; in the first, the equation was calibrated without regional-specific effects; in the other, the test was whether infrastructure should be included in the estimated system of equations. Both formulations were rejected. As far as the other category of public capital - social infrastructure - is concerned, it seems that this does not play a significant role in influencing the private sector.

Some of the conclusions to be drawn from an examination of the results can be summarised as follows. Infrastructure does have a significant and positive impact on the performance of private manufacturing, measured in terms of the cost elasticity with respect to public (productive) capital. It seems that public capital has a substitutive relationship with labour and intermediate inputs, and complementary one for private capital input. Put somewhat differently, infrastructure provision tends to save labour and other intermediate costs and it tends to lever additional investment in the private sector.

These results are in accordance with the results of production function analysis for the same period and same spatial analysis (Rovolis and Spence, 1997). However, a significant limitation of the dataset employed here is that it refers to manufacturing only, and that the latter is in aggregate form. Supplementary analysis extended to regional sectors of manufacturing, as well as to other activities of the private sector, has not been possible due to lack of data. Data limitations have also restricted the time dimension of this analysis to only 10 years.

As a concluding comment, one further set of findings can be reported, about which certainly more investigation is needed. If the values for simple single factor productivity are calculated (output per private input ratio), then these seem to be highly correlated with private input demand elasticities with respect to public infrastructure capital. Taking labour costs first, there is a distinct tendency for those regions with higher levels of labour productivity to substitute more infrastructure for labour inputs. Areas with high labour productivity tend to be associated with high negative elasticities for labour. A plausible explanation is that in remote locations the opportunities for externalising parts of the production process are small. Add extra infrastructure and the possibilities are raised and if taken up might possibly lead to labour shedding. Much the same can be said for intermediate private inputs into the production process. Conversely, there is a tendency for those regions with higher levels of capital productivity to benefit more, in terms of the leverage of private capital, from an additional unit of infrastructure investment. High capital productivity is associated with high positive elasticities for capital.

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[i] It seems that Ratner (1983) had earlier used the same analytical framework to that of Aschauer, that is to add public capital to a production function, in the US context. Nevertheless, it most certainly was Aschauer's work that put the role of public capital under the spotlight.

[ii] For a concise presentation of the various explanations for the productivity growth slowdown see Munnell (1990a).

[iii] W.E. Diewert not only introduced and developed some of the functional forms used in duality theory, which still form the basis for applied research (for instance his University of California-Berkley thesis in 1969 and his seminal article in the *Journal of Political Economy* (1971) „An application of the Shephard duality theorem: A generalized linear production function"), but he also provided a cost function analytical framework for public capital research (Diewert 1986).

[iv] There is, of course, the case in which the value of these services can be assessed with the use of a toll mechanism. It is assumed here that public capital services are a free public capital good. However, the arguments for the introduction of efficient toll mechanisms as the centrepiece of an efficient infrastructure policy are most relevant (see Holtz-Eakin 1993a, 1993c).

[v] 'Shadow value' is also sometimes called 'shadow price' (see Seitz 1994), or 'marginal benefit' of public capital (see Nadiri and Mamuneas, 1994).

[vi] This 'productive' group corresponds, more or less, to the concept of 'core' public capital used by Aschauer (1989a) and Munnell (1990a).

[vii] As there were no available estimates of the existing capacity of public capital, the method used by Corrales and Taguas (cited in Appendix 1 of Bajo-Rubio and Sosvilla-Rivero 1993) was employed. This considers the initial year as a basis, and then builds the stock of the subsequent years on it using the perpetual inventory method. The same methodology was employed for the construction of the private capital stocks

[viii] It has to be noted here that, in the published datasets of the Statistical Service of Greece, sometimes for certain prefectures the statistics are added together for confidentiality reasons. The dataset used here is based on the unpublished full prefectural breakdown.

[ix] For an illustration of this point see Berndt 1991, chapter 9, or Greene 1993, chapter 17.

[x] Note that the estimated set of equations has been divided by the price of the intermediate goods (p_m).

[xi] For an extensive presentation of this method see Berndt 1991, or Greene 1993.

[xii] For a more formal presentation of log-likelihood ratio test see Greene 1993. For its implementation in a cost function analysis context see also Berndt 1991.

[xiii] As there are no available data, at least on our knowledge, about the number of working hours, it has been assumed here that all workers in manufacturing have worked the same number of working days of year, for the same hours per day.

[xiv] The published data on labour remuneration refer to the wage bill paid to workers and employees excluding the employers' (insurance) contributions. However, the unpublished data from the Statistical Service of Greece provide information specifically about these contributions. There is the possibility that sectoral differences in the level of such payments might create anomalies in relation to the data that excludes them. In this analysis both datasets were tested and the results were similar. The subsequent results refer to the dataset including employers' contributions.

[xv] For this method of estimation of private capital price see Berndt and Hansson (1991a).

[xvi] These, as well as all other, indexes and data were obtained from the Statistical Service of Greece.

[xvii] Some researchers have argued that it is imperative to adjust public capital for capacity utilisation (Ford et al. 1991,Nadiri et al. 1994). In this research, however, the results with infrastructure adjusted for capacity utilisation (these figures for Greece are available only after 1982 and obtainable from the OECD) were similar to those for unadjusted public capital. It is the latter that are used here.

[xviii] As the coefficients are divided by every year's share in each prefecture, this means that for a specific prefecture there will be 10 such shares. The results refer to the average for every prefecture, as well as the total average.

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Table 1 Panel estimation results for manufacturing in the prefectures of Greece incorporating the effects of productive public capital, 1982-1991.

Variable	Estimated Coefficient	T-Ratio[a]
aO	14.171	237.854
aL	0.232	12.979
aK	0.292	8.228
aY	7.87E-01	32.980
aG	-5.93E-02	-1.545
aT	3.02E-02	5.487
bLK	3.13E-03	0.149
bLY	-3.33E-02	-4.989
bLG	-2.37E-02	-2.043
bLT	1.96E-03	1.160
bKY	-1.28E-01	-10.620
bKG	1.10E-01	5.373
bKT	1.04E-03	0.344
bYT	-1.67E-04	-0.241
	R-Square	Standard Error
Cost function	0.996	0.113
Labour share	0.785	0.033
Capital share	0.818	0.059
Log of Likelihood	2228.86	
	Likelihood ratio test[b]	Degrees of freedom
LRT_D	2076.86	147
LRT_G	76.02	3
LRT_Y	137.26	4

[a]Value of Ratio of Parameter Estimate to Asymptotic Standard Error. The total number of observations is 490.
[b]The associated p-values for all tests are 0.000.

Table 2 Likelihood ratio-tests for panel estimation results for manufacturing in the prefectures of Greece incorporating the effects of social public capital, 1982-1991.

	Likelihood ratio test[a]	Degrees of freedom
LRT_D	2019.4	147
LRT_G	4.72	3
LRT_Y	268.42	4

Table 3 Cost elasticities of manufacturing with respect to public infrastructure capital in the prefectures of Greece, 1982-1991.

Prefecture	ε_{CG}	Prefecture	ε_{CG}	Prefecture	ε_{CG}
Achaia	-0.062	Halkidiki	-0.062	Magnisia	-0.062
Aitoloakarnan.	-0.062	Ilia	-0.064	Messinia	-0.061
Arcadia	-0.061	Imathia	-0.061	Pella	-0.065
Argolida	-0.063	Ioannina	-0.066	Pieria	-0.062
Arta	-0.061	Iraklio	-0.064	Preveza	-0.064
Attiki	-0.064	Karditsa	-0.062	Rethimno	-0.062
Chania	-0.063	Kastoria	-0.061	Rodopi	-0.064
Chios	-0.059	Kavala	-0.061	Samos	-0.064
Dodekanissos	-0.061	Kerkyra	-0.062	Serres	-0.058
Drama	-0.064	Kilkis	-0.064	Thesprotia	-0.063
Evia	-0.062	Korinthia	-0.064	Thessaloniki	-0.062
Evritania	-0.063	Kozani	-0.058	Trikala	-0.063
Evros	-0.058	Kyklades	-0.064	Viotia	-0.061
Florina	-0.063	Laconia	-0.065	Xanthi	-0.062
Fokida	-0.065	Larisa	-0.062	ZakyKepha	-0.071
Fthiotis	-0.064	Lasithi	-0.062	Total Average	-0.063
Grevena	-0.063	Lesvos	-0.060		

Table 4 Factor bias effects over respective private input shares in the prefectures of Greece, 1982-1991.

Prefecture	bias LG	bias KG	bias MG	Prefecture	bias LG	bias KG	bias MG
Achaia	-0.165	0.285	-0.185	Kerkyra	-0.188	0.455	-0.160
Aitoloakarnan.	-0.184	0.602	-0.131	Kilkis	-0.164	0.450	-0.145
Arcadia	-0.165	0.746	-0.138	Korinthia	-0.589	0.599	-0.113
Argolida	-0.196	0.412	-0.143	Kozani	-0.146	0.196	-0.335
Arta	-0.164	0.511	-0.171	Kyklades	-0.051	0.503	-0.277
Attiki	-0.132	0.485	-0.153	Laconia	-0.370	0.284	-0.164
Chania	-0.221	0.871	-0.113	Larisa	-0.161	0.387	-0.152
Chios	-0.171	0.339	-0.168	Lasithi	-0.482	2.217	-0.100
Dodekanissos	-0.119	0.425	-0.164	Lesvos	-0.173	0.797	-0.127
Drama	-0.100	0.591	-0.154	Magnisia	-0.226	0.348	-0.151
Evia	-0.177	0.288	-0.178	Messinia	-0.175	0.614	-0.130
Evritania	-0.137	1.005	-0.163	Pella	-0.188	0.415	-0.143
Evros	-0.150	0.488	-0.152	Pieria	-0.132	0.274	-0.214
Florina	-0.164	0.716	-0.125	Preveza	-0.147	0.599	-0.137
Fokida	-0.196	1.391	-0.110	Rethimno	-0.144	0.416	-0.207
Fthiotis	-0.222	0.351	-0.149	Rodopi	-0.167	0.296	-0.178
Grevena	-0.096	0.237	-0.313	Samos	-0.220	0.250	-0.197
Halkidiki	-0.187	0.496	-0.133	Serres	-0.170	0.535	-0.138
Ilia	-0.233	0.313	-0.158	Thesprotia	-0.142	0.295	-0.416
Imathia	-0.197	0.569	-0.128	Thessaloniki	-0.188	0.514	-0.132
Ioannina	-0.232	0.401	-0.138	Trikala	-0.167	0.535	-0.135
Iraklio	-0.240	0.406	-0.139	Viotia	-0.247	0.215	-0.225
Karditsa	-0.266	0.847	-0.111	Xanthi	-0.192	0.308	-0.165
Kastoria	-0.113	2.192	-0.123	ZakyKepha	-0.212	0.450	-0.141
Kavala	-0.168	0.307	-0.174	Total Average	-0.193	0.556	-0.165

Table 5 Private input demand elasticities with respect to public infrastructure capital in the prefectures of Greece, 1982-1991.

Prefecture	ε_{LG}	ε_{KG}	ε_{MG}	Prefecture	ε_{LG}	ε_{KG}	ε_{MG}
Achaia	-0.227	0.223	-0.247	Kerkyra	-0.250	0.393	-0.221
Aitoloakarnan.	-0.246	0.540	-0.193	Kilkis	-0.228	0.386	-0.209
Arcadia	-0.226	0.685	-0.199	Korinthia	-0.653	0.535	-0.178
Argolida	-0.258	0.350	-0.206	Kozani	-0.204	0.138	-0.393
Arta	-0.226	0.449	-0.232	Kyklades	-0.115	0.439	-0.341
Attiki	-0.196	0.421	-0.216	Laconia	-0.436	0.219	-0.229
Chania	-0.284	0.808	-0.176	Larisa	-0.223	0.325	-0.214
Chios	-0.230	0.280	-0.227	Lasithi	-0.544	2.155	-0.162
Dodekanissos	-0.180	0.364	-0.225	Lesvos	-0.234	0.736	-0.187
Drama	-0.163	0.528	-0.217	Magnisia	-0.289	0.286	-0.213
Evia	-0.239	0.226	-0.240	Messinia	-0.236	0.553	-0.191
Evritania	-0.200	0.942	-0.227	Pella	-0.253	0.350	-0.208
Evros	-0.209	0.430	-0.210	Pieria	-0.194	0.212	-0.276
Florina	-0.226	0.653	-0.188	Preveza	-0.212	0.535	-0.202
Fokida	-0.261	1.326	-0.175	Rethimno	-0.206	0.355	-0.269
Fthiotis	-0.285	0.288	-0.213	Rodopi	-0.231	0.232	-0.242
Grevena	-0.159	0.174	-0.376	Samos	-0.285	0.185	-0.261
Halkidiki	-0.248	0.435	-0.194	Serres	-0.228	0.476	-0.196
Ilia	-0.296	0.249	-0.222	Thesprotia	-0.205	0.232	-0.479
Imathia	-0.258	0.508	-0.189	Thessaloniki	-0.249	0.452	-0.194
Ioannina	-0.298	0.336	-0.204	Trikala	-0.230	0.472	-0.198
Iraklio	-0.305	0.342	-0.203	Viotia	-0.308	0.154	-0.286
Karditsa	-0.328	0.785	-0.173	Xanthi	-0.254	0.246	-0.227
Kastoria	-0.174	2.131	-0.184	ZakyKepha	-0.282	0.379	-0.212
Kavala	-0.230	0.246	-0.235	Total Average	-0.255	0.493	-0.228

Table 6 Shadow values of public infrastructure capital in the prefectures of Greece, 1982-1991.

Prefecture	s_{Gi}	Prefecture	s_{Gi}	Prefecture	s_{Gi}
Achaia	1.098	Halkidiki	0.070	Magnisia	1.121
Aitoloakarnan.	0.090	Ilia	0.097	Messinia	0.150
Arcadia	0.056	Imathia	1.133	Pella	0.301
Argolida	0.186	Ioannina	0.134	Pieria	0.212
Arta	0.072	Iraklio	0.214	Preveza	0.084
Attiki	0.713	Karditsa	0.110	Rethimno	0.007
Chania	0.067	Kastoria	0.039	Rodopi	0.118
Chios	0.028	Kavala	0.509	Samos	0.076
Dodekanissos	0.035	Kerkyra	0.044	Serres	0.280
Drama	0.264	Kilkis	0.429	Thesprotia	0.068
Evia	1.211	Korinthia	2.645	Thessaloniki	1.093
Evritania	0.056	Kozani	0.364	Trikala	0.143
Evros	0.046	Kyklades	0.066	Viotia	1.654
Florina	0.018	Laconia	0.028	Xanthi	0.602
Fokida	0.079	Larisa	0.473	Zaky-Kepha	0.036
Fthiotis	0.934	Lasithi	0.020	Total Average	0.353
Grevena	0.004	Lesvos	0.038		