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PUBLIC INFRASTRUCTURE AND PRIVATE OUTPUT: AN APPLICATION TO GREECE

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Recently, it has been announced by economic policy makers, that Greece's ambition for the 21st century is to become a business and transport hub, linking south-east Europe with EU markets. Undoubtedly, public infrastructure plays a determinant role in fulfilling these expectations and plans. Nevertheless, the impact of public infrastructure on Greek economy has rarely been systematically examined at an empirical level. In this paper we take into account some of the points of the underlying criticism in the literature to empirically investigate the possible links between public infrastructure and Greek productivity. More precisely, we use cointegration techniques and vector autoregression (VAR) analysis in order to derive the long run relationship and the short run dynamics between public infrastructure and private output. Our results indicate that a one percent increase in public infrastructure enhances the productivity of the Greek industrial sector by 0.14 percent.

Keywords: Public Infrastructure, Private Productivity, Cointegration Tests, VAR, IRF, VDC
JEL classification: H54, E2, E62

1. INTRODUCTION

"*Everyone agrees that public capital investment can expand the productive capacity of an area by both increasing resources and by enhancing the productivity of existing resources*" Munnel (1992).

In this paper, rather than imposing Munnel's perspective, we consider it as plausible, though not necessarily true. It is up to the empirical analysis to provide some evidence. Specifically, we investigate whether public infrastructure affects the output and productivity of the Greek industrial sector.

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The case of Greece is of a particular interest, since it experienced both political and economic upheaval through the 1950-1995 time period. Greece demonstrated outstanding economic performance in the fifties and sixties. The average annual percentage growth of GNP in the fifties and sixties was 6.2 per cent, second only to Japan among the OECD countries, while the average annual percentage change of fixed investment followed a similar pattern, 6.3 per cent. However, late in the seventies and the eighties the growth of the Greek economy slackened. The average annual percentage growth of GNP in this period fell to 1.2 per cent, while fixed investment dramatically declined to 0.8 percent.

Like all small economies, Greece is strongly dependent on external links with other economies. Thus, maintenance of a strong competitive position is vital. One would expect, therefore, that a country at the periphery of EU would have developed an extended infrastructure network. Alas, Greece has a poor level of public infrastructure compared with the rest member-states of EU (European Commission (1993)). Moreover, Greece followed a type of ‘defensive maintenance’ strategy for existing infrastructural networks, despite the fact that there was widespread recognition of the importance of constructing major infrastructure projects as a way of restructuring the economy and making it attractive to private business.

The lack of infrastructure investment in the seventies and eighties contradicts an observed spree in public expenditures, which rose as per cent of GNP from 27 per cent in the sixties to 48.2 per cent in the late eighties. Clearly, investment in public infrastructure was depressed by a stable decline in public investment. Public investment fell from 6.5 per cent of GNP in the sixties to 4 per cent in the late eighties, while public expenditures for transfer payments and goods and services more than doubled in the same period. Apparently, public investment played a residual role within the structure of public expenditures. As a result, Greece experienced a sharp decline in the growth rate of infrastructure from 7.2 per cent in the sixties to 1.8 per cent in the late eighties. This development clearly acted as an impediment to the economic prosperity of the country. In fact one of the major problems in Greece was the reported low productivity growth in the eighties (see Christodoulakis (1993)). The emerging question is whether infrastructure should be, at least partly, held responsible for the economic stagnation of the country?

The impact of public infrastructure on the Greek economy has, however, rarely been systematically examined in an empirical study (Christodoulakis (1993)). This is partly due to the fact that economic research has overlooked the potential importance of public capital in the production function of private sector of the economy. Late in the eighties and in the nineties, has a sequence of papers attempted to provide empirical evidence for the relationship between public infrastructure and output. Table 1 summarises the main methodological approaches as well as the main findings for some of those papers.

Some of those studies reported high output elasticities of public infrastructure i.e., Aschauer (1989a), Holtz-Eakin (1994), and Munnel (1990a). These results have sparked serious concerns about their plausibility. Evans and Karras (1994) argue that in general it is hard to accept that the marginal productivity of public infrastructure exceeds 100%, and it is higher than the marginal productivity of private capital. One can not also fail to notice that the magnitude of the output elasticity with respect to public infrastructure varies depending on the level of aggregation.

Table 1. Production Function Estimates of the Output Elasticity of Public Capital

Author	Level of Aggregation	Specification	Output Elasticity of Capital Stock
Ashauer (1989a)	National (USA)	Cobb-Douglas: log levels	0.39
Holtz-Eakin (1994)	National (USA)	Cobb-Douglas: log levels	0.39
Munnel (1990a)	States (USA)	Cobb-Douglas: log levels	0.34
Costa *et al*. (1987)	States (USA)	Translog: levels	0.20
Eisner (1991)	States (USA)	Cobb-Douglas: log levels	0.17
Mera (1973)	Japanese Regions	Cobb-Douglas: log levels	0.20
Munnel (1990b)	States (USA)	Cobb-Douglas: log levels	0.15
Deno *et al*. (1989)	Metropolitan Areas (USA)	Log levels	0.08
Eberts (1986, 1990)	Metropolitan Areas (USA)	Translog: Levels	0.03

There are many issues that have been raised as possible explanations of the above striking results. In this paper we take into account the issue of the existence of stochastic inherent trend in the underlying data generating processes, which can result in meaningless statistical inference of standard regressions techniques (Lynde and Richmond (1992)). Therefore, we deal with the problem of having non-stationary time series, which may lead to spurious correlation in the estimated relations. We argue that an appropriate way to overcome this difficulty is to apply unit root tests, and then to examine whether a meaningful relationship between public infrastructure and private sector output exists both in the long and short run.

The results of this paper reveal the positive effect of public infrastructure on output and private capital productivity of the Greek industry. They also demonstrate that the causal relationship between them is from the side of public infrastructure to the side of productivity rather than the other way around.

In what follows, Section 2 describes a theoretical specification, Section 3 offers an empirical application, and Sections 4 and 5 present the main findings of our analysis. Finally, Section 6 concludes with a brief overview and some policy considerations.

2. A THEORETICAL SPECIFICATION

In this paper we follow a simple theoretical model in line with the one presented by Arrow and Kurz (1970). A similar specification has also been used in numerous other studies (Aschauer (1989a), Munnel (1990a)). Moreover, our production function follows a Cobb-Douglas specification, which takes the following form:

$$Y_t = A_t K_t^a L_t^b G_t^g , \tag{1}$$

where Y_t is private real output, A_t is a measure of technological progress, K_t is real capital stock, L_t is private labour input, and G_t is public infrastructure. The implied assumption of the above production function is that private real output is supported by the flow of services from private and public infrastructure.[1]

By taking logarithms (1) can further be written as:

$$\ln Y_t = \ln A_t + a \ln K_t + b \ln L_t + g \ln G_t + u_t . \tag{2}$$

The coefficients a , b , and g represent the private output elasticities with respect to private capital stock, private labour, and public infrastructure respectively. Our attention focuses on g , which is used to infer whether services derived from public infrastructure assist the production of a higher level of output. Notice that in Equation (2) no restriction on the returns to scale is imposed. Thus, the sum of coefficients a , b , and g , can take any value, depending on whether the returns to scale are increasing, constant, or decreasing over all inputs.

3. DESCRIPTION OF DATA AND UNIT ROOT TESTS

In a preliminary stage of our research we confronted with data limitations. However, the Greek industrial sector has provided all the necessary data for the purposes of our empirical analysis. By opting for a disaggregated data set (i.e., industrial production) we

[1] This assumption has been extensively discussed in Fisher (1997). Further data limitations restrict our choices of using public services derived from public capital stock. However, to the best of our knowledge the use of public capital stock as an approximation of public services is dominant.

deal with one of the main criticism against the importance of public infrastructure, which argues that high degree of aggregation would unavoidably lead to high output elasticities with respect to public infrastructure (Munnel (1992)). This criticism is mainly explained by a possible feedback from private output to public infrastructure, insinuating that the latter might be an endogenous variable that could cause simultaneity bias. However, at a disaggregated level, one would not expect the industrial output to determine the overall stock of public infrastructure. In addition, we apply an empirical estimation specification, which allows all variables in the Cobb-Douglas to enter as endogenous within a system of equations.

Our data set is obtained from various institutes in Greece; the National Statistical Office of Greece, the Centre of Planning and Economic Research (KEPE), and The Ministry of National Economy. The frequency of our time series is annual, and the sample covers the period from 1959 to 1997.

Data for value added, private capital stock and employment were obtained from the annual industrial survey of Greece published by the National Statistical Office of Greece (ESYE, various issues). Large-scale manufacturing industries were included in the data set, which covers industries with an average annual employment of at least twenty persons. All time series are deflated by the whole price index for industrial products derived from the Annual Industrial Survey of ESYE (various issues).

The time series of public capital stock has been provided by two different sources, the Ministry of National Economy and the Centre of Planning and Economic Research (KEPE, Skoutzos (1993)). These time series have been computed on the base of perpetual inventory method, using real gross investment, a benchmark for capital stock, and a measure of economic depreciation. We opt to define public infrastructure as ‘core’ in line with previous studies (Ashauer (1989), Munnel (1990), and Ford and Poret (1992)). Core infrastructure encompasses the portion of public capital stock that can directly facilitate private production, Greek industrial output in our case.

In this way we presume that core infrastructure has a-priori supply side effects on private output. Any demand side effect of infrastructure on private output is excluded by simply not taking into account projects that have such effects on output.[2] Core infrastructure includes capital stock in ports, railways, civil aviation, roads, electricity

[2] One may consider public investment projects as having strong demand side effects on output. For example, there exist projects that recreate the environment where people live and work. The construction of a park does indeed increase the utility of individuals but does not directly increase industrial output, though indirectly the derived by the individuals utility from the park may raise their productivity and consequently the production. Fisher (1997) strongly supports the view to take into account the indirect effects of public infrastructure and then to compare with the impact of direct effect on the welfare of the economy. Given data limitations, however, we opt for ‘core infrastructure’, aiming to investigate the relationship between the former and private productivity of industrial production.

and communications.[3]

Our next step is to test whether our time series are stationary over time, i.e., whether they exhibit some kind of deterministic or otherwise stochastic trend. Non stationary time series cause spurious correlation with purely coincidental low frequency movements that result in biased estimates, and do not allow a statistical interpretation of the estimations. Thus, the use of non-stationary variables can lead to spurious regressions. The obtained result of such regressions may falsely suggest that there is a statistically significant relationship between the variables of the model, though in reality what is actually obtained is evidence of a contemporaneous correlation rather than a causal relationship.

In this paper the Augmented Dickey Fuller (ADF) statistic is used as a test for unit roots. Furthermore, the ADF test includes additional higher order lagged terms to account for the case that the underlying data generating process is not a simple autoregressive (AR) process of order one. Phillips and Perron (1988) give an alternative approach. Their test is based on a non-parametric correction to the *t*-test statistic in order to correct for autocorrelation whenever the underlying data generating process is not as simple as AR(1). Table 2 reports both ADF and PP test results in levels and first differences.

Table 2. Unit Root, ADF and Phillips Perron Tests

Variables	ADF(1 lag)	ADF(2 lags)	PP(1 lag)	PP(2 lags)
y	-2.63	-0.45	-2.25	-2.15
l	1.12	0.69	1.59	1.34
k	-2.81	-2.54	-3.05*	-3.05*
g	-2.29	-2.25	-2.87	-2.91
Δy	-8.00**	-3.62*	-5.31**	-5.28**
Δl	-5.05**	-3.16	-5.46**	-5.58**
Δk	-4.22**	-3.97*	-4.51**	-4.47**
Δg	-4.58**	-3.60*	-4.36**	-4.29**

Notes: * (**) indicates significance at 5% (1%) level. The critical values are from Dickey-Fuller (1981). The variables are defined as follows: y = log of value added, l = log of number of employees, k = log of private capital stock, g = log of public capital stock, y - k = log value added/private capital stock. The lag value (2) is found to correct for serial correlation in the regressions for unit root tests.

[3] In contrast with other member states of EU the provision and distribution of electricity and fixed telephony services is owned by public enterprises in Greece. These enterprises constitute the biggest natural monopolies. Only recently OTE, the telecommunication company, has entered Athens stock exchange market, and its shares were strictly spread in a wide base of investors to remain effectively a central controlled enterprise.

The reported statistics suggest that our time series have a unit root and thus they are integrated of order 1, I(1). Notice, however, that the tests for private capital stock do not give a clear answer about the order of integration. Knowing that ADF and PP tests are very sensitive in finite samples, exhibiting signs of low power, we have to search for more evidence about the order of integration. We have observed that the autocorrelation function of private capital stock declines slowly over time towards zero. As a consequence private capital stock can be regarded as having one unit root. In addition, ADF test for private capital stock indicates that it is clearly an I(1) time series.

The next section investigates whether our time series grow together over time and converge to a long-run solution. This essentially means that we test for possible cointegration relationships among our variables in line with the analysis of Engle and Granger (1987).

4. AN EMPIRICAL APPLICATION

Deriving a statistically meaningful interpretation of a regression model using non-stationary time series requires taking their first differences. By doing so the stochastic trend of their underlying data generating process is eliminated. However, Munnel (1990a) mentioned that any long run relationship that the time series might encompass is removed by first differencing them. Similarly, Pollock (1997) argued that first differencing is a very cruel way of filtering or detrending time series because the loss of information is enormous compared with the gains. A novelty feature of this paper lies on testing for a cointegration relationship among the variables of our model so as to tackle the lost information problem from just first differencing. By doing so we expect to capture the long-run impact of public infrastructure on private output.

But what does cointegration mean? Essentially cointegration describes a linear combination among economic variables, which gives residual integrated of order 0, I(0). Thus even when the variables are non stationary it is possible to derive a long-run equilibrium among them without suffering from the statistical problems of spurious estimation of the underlying regression model.

In detail, following Sims (1980) we set a vector, X_t, of n potentially endogenous variables and subsequently we model X_t as an unrestricted vector autoregression (VAR) with k lags. The derived data generating process takes the following form:

$$X_t = A_1 X_{t-1} + \ldots + A_k X_{t-k} + u_t , \qquad u_t \sim IN(0, \Sigma) , \tag{3}$$

where X_t is a $(n \times 1)$ vector and A_i is a $(n \times n)$ matrix of parameters.

In our empirical analysis vector X_t contains the four main variables; value added (y), private labour input (l), private capital stock (k) and a public infrastructure (g). The advantage of the above VAR is mainly its ability to estimate dynamic relationships among the variables without imposing strong a priori restrictions. This VAR can be further transformed in to the following vector error correction model (VECM).

$$\Delta X_t = \Gamma_1 X_{t-1} + \Gamma_2 \Delta X_{t-2} + \ldots + \Gamma_{K-1} \Delta X_{t-k-1} + \Pi X_{t-K} + e_t , \quad (4)$$

where X_t is a (4×1) vector of the variables y_t, l_t, k_t, and g_t, e_t is a (4×1) vector of white noise errors, $\Gamma_i = -(I - A_1 - \ldots - A_i)$ contains information on the short run adjustment to changes in X_t, while $\Pi = -(I - A_1 - \ldots - A_k)$ contains information on the long run adjustment. The matrix Π can be decomposed into $\Pi = ab'$, where a is a $(n \times r)$ adjustment matrix, representing the speed of adjustment to dis-equilibrium, while b is a $(n \times r)$ cointegration matrix of long-run coefficients, such that $b' X_{t-k}$ represents up to $(n-1)$ cointegration relationships in the multivariate model, which ensure that the matrix X_t converge to the long run steady state solution.

The above multivariate system has $n-1$ cointegration vectors only if ΠX_{t-K} is stationary, since ΔX_{t-i} is stationary.[4] In that case $r \leq (n-1)$ cointegration vectors exist in b matrix. Equivalently 'r' columns of b form 'r' linearly independent combinations of the variables in X_t, each of which is stationary. Notice that only the cointegration vectors in b enter the system of equations, since otherwise ΠX_{t-K} would not be I(0). Testing for cointegration is essentially a search of how many 'r' linearly independent columns exist in Π, or alternatively defining the rank of Π. Johansen (1991) develops a technique in order to obtain maximum likelihood method estimations of a and b. The specific technique is named as reduced rank procedure after its main function, which is to define the rank of Π.

The time series of Equation (2) appear to have an inherent drift. Therefore, using an unrestricted constant in the multivariate system of equations (VECM), which allows a non-zero drift in the unit root process, is an adequate way to treat them. Pantula's principle of choosing the appropriate specification for our time series is also applied by estimating three different models.[5] These empirical estimations confirm that the most

[4] We have seen that X_t is a vector of non stationary variables, the variables y_t, l_t, k_t, and g_t, are I(1), and therefore ΔX_{t-i} is I(0).

[5] Johansen (1992) was the first to suggest the use of the Pantula principle to test the joint hypothesis of both rank order and the deterministic components within VECM. This principle is based on the estimation of the following alternative models: i) in the first model it is assumed that there no linear trends in the levels of the data and the intercept is restricted to the long run, ii) in the second model there are linear trends in the levels of the data and the intercept is unconstraint and exists in the short-run, iii) finally according to the less restrictive model there are no quadratic trends in the levels of the data and the cointegration space includes time as a trend stationary variable. The test procedure compares the results using the trace (l_{max}) test statistic

appropriate model is the one with linear trend in the underlying data generating process and with an unconstrained constant. In addition, to Pantula's principle we also apply Akaike and Schwarz's criteria (test results are available on request). It is also found that a lag length equal to 2 is sufficient to ensure that the residuals of the multivariate system are Gaussian, being normally distributed and not suffering from serial autocorrelation and heteroscedasticity.

Having specified the appropriate model and lag value for the underlying data generating process we can subsequently test whether the Π matrix has a reduced rank. That is to find whether $r \leq (n-1)$ cointegration vectors exist in b .

Table 3 presents the diagnostic tests for serial correlation (F_{AR} against first order serial correlation), autoregressive conditional heteroscedasticity (F_{ARCH}), heteroscedasticity (F_{het}), and normality (X^2) of vector error correction model (VECM thereafter). The reported test statistics imply that the null hypotheses of no serial correlation, no ARCH, and no heteroscedasticity respectively, are not rejected, indicating that our model has the standard statistical properties. However, there is indication of non- normality, which is less of a problem within a multivariate system of equations according to Johansen (1991).

Table 3. Test Summary for the Evaluation of Statistical Properties of the Model

	y	*k*	*l*	*g*
$F_{AR}(1, 27)$	2.27 [0.123]	0.41 [0.6675]	2.02 [.153]	2.38 [0.1140]
$F_{ARCH}(1, 23)$	1.03 [0.319]	0.57 [0.4565]	.842 [.367]	0.023 [0.8657]
$F_{het}(1, 31)$	.020 [0.887]	0.52 [0.7821]	0.0003 [.9]	1.319 [0.2988]
$X^2(2)$norm.	8.06 [0.018]	0.36 [0.8321]	17.76 [.00]	0.381 [0.8265]

Notes: The null hypotheses are that there is no serial correlation, no ARCH, no heteroscedasticity, and non normality respectively. The numbers in parenthesis report the probabilities of rejecting the null, when it should be accepted.

Table 4 presents the maximum likelihood eigenvalues statistics. The null hypothesis is that there is no cointegration relationship, so $r = 0$. It becomes clear from the table that the null hypothesis of no cointegration is rejected at 1% level (see Osterwald-Lenum, 1992 for critical values). More precisely, trace and l -max statistics are significant at 1% level rejecting the hypothesis of no reduced rank in favour of reduced rank equal to one. Consequently, Π has reduced rank of 1. One cointegration vector is therefore present in b , suggesting that a unique long run relationship between private output, private labour, private capital and public infrastructure exists.

of cointegration and accepts the model that the null hypothesis is not rejected.

Table 4. Johansen's Maximum Likelihood Method Test for Cointegration Relationship (number of lags = 2).

Ho: rank = *r*	l_{MAX}	using T-nm	95%	l_{Trace}	using T-nm	95%
$r = 0$	32.66**	24.74	27.1	58.7**	44.47	47.2
$r < = 1$	15.47	11.72	21	26.04	19.73	29.7

Notes: *(**) indicates significance at 5% (1%) level. T-nm are l_{MAX} and Trace statistics adjusted for the number of degrees of freedom. The 95% columns report the critical values of Osterwald-Lenum (1992).

The resulting normalised parameter estimates of our model from the cointegration analysis are as follows:

$$y = 0.81l + 0.32k + 0.14g, \quad (5)$$
$$(0.22) \quad (0.05) \quad (0.03)$$

where the numbers in parentheses denote *t*-statistics.

The effect of public infrastructure, g, on private output is positive and quite substantial in magnitude. One percent increase of public infrastructure results in an increase of private output by 0.14%. While the output elasticities with respect to private labour and private capital are 0.81 and 0.32 respectively.

One of the main skepticism in the literature concerns the magnitude of the impact of public infrastructure on private output (Evans and Karras (1994)). Intuitively it is rather difficult to accept that within a production framework the implied marginal product of public capital stock is higher than that of private capital stock.

The above reported empirical evidence implies that taking into account the non stationary nature of our time series we are able to obtain plausible output elasticities with respect to public infrastructure. To clarify further the validity of these findings we use the parameter estimates for private and public capital stock from Equation (5) to compute their marginal products. Figure 1 presents these marginal products.

Undoubtedly, the output elasticity with respect to public capital of 0.14 is too substantial to be just ignored. It is reasonable, therefore, to expect that building up infrastructure may enhance the productivity of Greek industrial sector and may support the ever-lasting industrialisation of the country, thereby benefiting the whole economy. Our findings validate this expectation and reveal that public investment in infrastructure can be viewed as a macroeconomic tool against chronic stagnation in productivity.

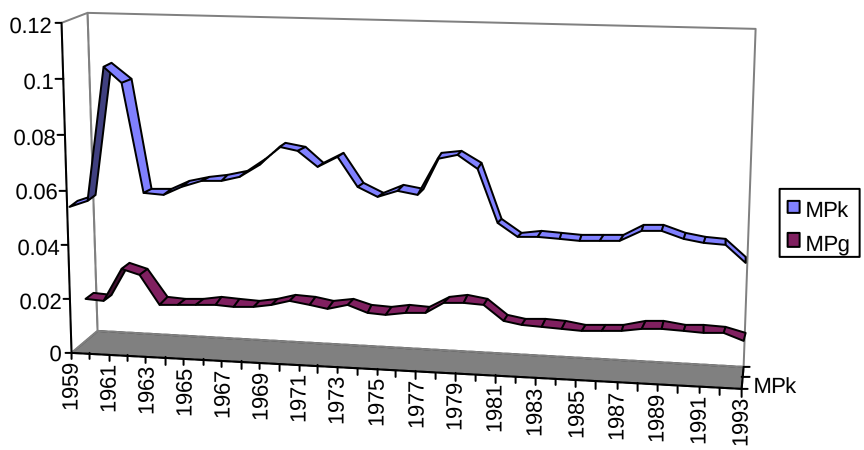

Figure 1. Marginal Products of Private Capital Stock (MP_k) and Public Infrastructure (MP_g).

5. EMPIRICAL ANALYSIS ON SHORT RUN DYNAMICS USING VAR MODEL

This section concentrates on the effect of public capital stock on private inputs of production and private output in the short run using a Vector Autoregressive (VAR) model. This analysis can reveal further in detail whether there is a causal relationship between public capital stock and the rest of the variables within the production function, and can also accurately indicate the direction of causality.

The lag value of the VAR is set equal to three. Toda and Yamamoto (1995) suggest that standard asymptotic theory still applies in a VAR, even when the variables of the model are known to be non stationary, as long as the order of integration of the underlying data generating process does not exceed the chosen lag length of the model. Their finding implies that using non-stationary time series in a VAR is applicable once $p+d$ lags have been selected, where p is the true lag length of the model and d is the order of integration of the variables. Knowing that the order of integration of our variables is one and that $p=2$, we estimate a VAR(3). Changes to the lag length were not found to alter the results of our empirical analysis.

Following Sims (1980) impulse response functions (IRF thereafter) and variance decomposition (VDC) are plotted and calculated respectively. A linear trend is present in the unconstrained VAR acting as an approximation of the inherent trend of the underlying data generating process of our data set.

Before proceeding in the presentation of IRF and VDC it is worth mentioning that the ordering of the variables of our model may considerably alter the outcomes of the analysis. Different recursive structures of VAR corresponds to different choices of ordering as Sims (1992) emphasises. He also states that variables listed earlier in the VAR contemporaneously influence the variables listed later, while the opposite does not hold. Therefore, a suitable way of ordering variables is to list first the exogenous followed by the endogenous. This essentially requires an a-priori theoretical knowledge. In our case the Cobb-Douglas production function provides a specific theoretical framework for our time series, where private output is the only endogenous variable. Therefore, we order our variables as following; public infrastructure, private capital stock, private labour and private output (g, k, l, and y).[6]

The IRF derived from the unrestricted VAR are presented in Figure 2. More precisely, Figure 2 reports the response of each variable of the VAR to its own innovation and to the innovations of other variables. Standard deviations confidence bounds are also reported in order to test the significance of the responses.[7] The time period of IRF function spreads over ten years, which is a long enough period to capture the dynamic interactions between public infrastructure and the remaining variables of the VAR.

From the second row of Figure 2, it becomes apparent that the effect of one standard deviation shock of public infrastructure on private capital stock is positive and significant for a period of seven years. Subsequently, the confidence bounds become very wide, driving the response of private capital stock to public capital infrastructure insignificant. The peak response of private capital stock to innovations of public infrastructure occurs six years after the initial shock, stabilising thereafter. This finding indicates that building up public capital stock can indirectly enhance private capital stock. Private capital stock and public infrastructure can be, therefore, treated as complements in the production procedure.

Figure 2 further shows that the response of private capital stock to a one standard deviation shock of public capital stock is approximately estimated to be 0.02 percent per annum for a period of seven years. In other words, a one- percent increase in public capital stock's innovation causes a 0.02 percent increase in private capital stock. What we observe from the IRF is a crowding in effect from public infrastructure to private capital stock.[8] On the other hand, public capital stock response to private capital stock

[6] To count also for the criticism in favour of an endogenous public infrastructure we estimate IRF and VDC using the alternative ordering; private capital stock, private labour, private output and public infrastructure (k, l, y and g). In this case public capital stock is assumed to be the most endogenous variable of the VAR. IRF diagrams and VDC for this ordering are available on request.

[7] If the confidence interval bounds pass through the zero line or the bounds are very wide then the response of a variable to disturbances is considered to be insignificant.

[8] Ashauer (1989b) also finds that there is indeed a crowding in effect from public infrastructure to private

innovation is insignificant and negative.

Johansen's cointegration tests have shown that there is a long run positive relationship between public infrastructure and private output. In the literature this relationship is challenged by a possible feedback from private output to infrastructure. It is conceivable that in recessional periods, when output and taxes are at low levels, the government is less willing to finance infrastructure projects, while when the economy is growing and a higher level of taxes are collected, public investment is also increased. The empirical evidence so far does not support this argument, public infrastructure is a rather exogenous variable, which is not influenced by private industrial output. The response of public capital stock to innovation of private output is effectively zero. On the other hand, the effect of a shock in public capital stock on private output is positive and significant after the fourth year, implying that it is realised in the long run.

Figure 2 also shows that the response of private employment to innovation of public capital stock turns positive after the fourth year. Policy makers in Greece often tend to believe that public investment can be used as an automatic mechanism of creating employment places. This does not seem to be the case for the industrial sector of the economy at least in the short run. However, as we have seen, in the long run public capital stock increases private capital productivity, which may indirectly increase employment by raising the marginal product of labour and labour demand. A higher private capital productivity leads to a higher level of private investment, a higher level of production, and eventually a higher level of employment. Along these lines IRF indicates that the response of private employment to innovation of private capital stock is significant and positive for six years, and then it becomes negative .

Next, the variance decomposition (VDC thereafter) is estimated for each variable in the VAR for a period of ten years. That is the proportion of forecast error variance of private output, private labour, private capital stock and public infrastructure, due to their own, or others, one standard deviation shock is calculated.

The VDC estimation results for 10 years ahead are presented in Table 5. These results seem to be in agreement with those of IRF, providing evidence in favour of the importance of public capital stock to explain variation in private purchased inputs, and especially private capital stock. As the years pass public capital stock gradually affects more the variation of private capital stock, while private employment and private output explain very little of the specific variation. More precisely, 76.6 percent of private capital stock forecast error variance in a ten years period is explained by disturbances of public capital stock. This figure is quite substantial, underlying the importance of providing public capital stock for the private sector. On the other hand, the variation of public capital stock is largely explained by its own innovations. Consequently, public infrastructure can be treated as an exogenous variable.

capital stock through an increase in the productivity of the latter caused by the former, although initially a crowding out effect prevails.

Private employment's variation is mainly due to its own innovation for the first seven years. After the ninth year, a substantial part of the forecast error variance of the private employment, 37.9 percent, is affected by the disturbance of public capital stock. However, comparing this figure with the outcome of IRF, we can observe that the response of private employment to innovation of public capital stock although it becomes clearly positive after the fourth year it has wide statistical significance bounds, and as a result it is doubtful. Therefore, we remain rather skeptical to accept that public capital stock can indeed explain a big portion of variation in private employment.

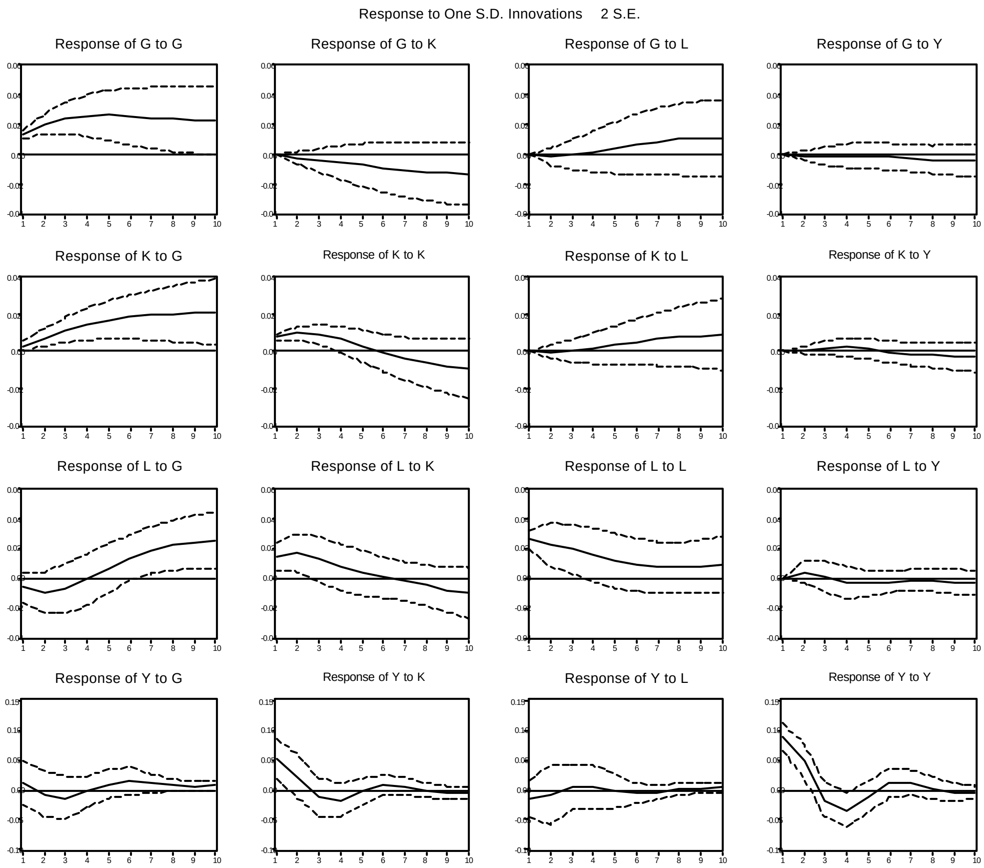

Figure 2. Impulse Response Functions

Table 5. Variance Decomposition (ordering *g*, *k*, *l*, *y*)

Variance Decomposition of G:					
Period	SE	G	K	L	Y
1	0.013176	100.0000	0.000000	0.000000	0.000000
4	0.043710	96.48199	3.049228	0.307181	0.161596
7	0.064869	88.97128	7.313798	3.355123	0.359800
9	0.076337	82.74885	10.37602	6.084530	0.790595
10	0.081592	80.23109	11.61769	7.176405	0.974814
Variance Decomposition of K:					
Period	SE	G	K	L	Y
1	0.008290	14.48768	85.51232	0.000000	0.000000
4	0.026629	59.58697	38.79069	0.371944	1.250391
7	0.042578	78.35099	16.49481	4.462893	0.691310
9	0.053838	77.94365	13.92752	7.295062	0.833767
10	0.059403	76.67197	14.00689	8.366709	0.954436
Variance Decomposition of L:					
Period	SE	G	K	L	Y
1	0.030446	4.263624	22.73428	73.00210	0.000000
4	0.051915	6.968155	26.13033	65.97231	0.929205
7	0.059860	21.60148	20.05840	57.03934	1.300778
9	0.069738	37.97843	16.53076	44.36599	1.124817
10	0.075465	43.75698	15.83806	39.25936	1.145605
Variance Decomposition of Y:					
Period	SE	G	K	L	Y
1	0.104406	1.180013	23.70142	1.976759	73.14180
4	0.126741	2.260708	22.20683	2.093953	73.43850
7	0.130410	4.522156	21.59527	2.298555	71.58402
9	0.130982	5.024523	21.53525	2.332668	71.10756
10	0.131356	5.288734	21.52670	2.386251	70.79832

Variations in private output are mainly explained by its own innovation and innovation of private capital stock. Over the years there is an increase of the importance of public capital stock to explain variation in private output, confirming the long run relationship found to hold among them by the Johansen cointegration analysis. On the other hand, private output innovation does not substantially explain the variation of public infrastructure, suggesting a one way relationship, from the latter to the former.

6. CONCLUSION

It is frequently quoted (see European Commission (1995)) that one of the main inefficiencies, which the Greek economy has to overcome so as to converge towards the rest member-states of the EU, is the construction of an adequate level of public infrastructure. Adequacy in infrastructure is closely linked with achieving a level of public infrastructure that could enhance the productive capabilities of the economy, and thus boost economic growth. In fact, Greek infrastructure is being modernised with the help of grants from EU. The incoming European structural funds amount to more than 5 percent of annual GDP for the period 1993-2000. In many respects, EU has forced successive Greek Governments to create a development plan with a major element the investment in basic infrastructure, like transport, telecommunications, and energy. As a result, in the nineties, economic policy makers recognised the importance of public infrastructure to strength Greek competitiveness within EU and to facilitate the development prospects of the economy in an attempt to close the productivity gap between Greece and EU. An integrated European market is anticipated to boost economic growth, and, therefore, induce higher demand for infrastructure, especially for cross borders-transportation links.

Along these lines in 1999 it was announced that Greece's ambition for the 21st century is to become a business and transport hub, linking south-east Europe with EU markets. Undoubtedly, public infrastructure plays a determinant role in fulfilling these expectations and plans. A new international airport has been recently constructed in Athens so as to deal with a growing number of cargo load and visitors for the Olympic games in 2004. An expansion of the metro is also underway, in order to link the new airport with the center of the city. The modernisation of the existing motorways and the creation of new ones has also been planned. Among the most significant road projects is the 680 Km Egnatia highway, which will link Adriatic Sea with the Turkish border. This project is expected to invigorate a relative underdeveloped and de-industrialised geographical area, namely that of Thrace (the north east part of the country).

Our findings appear to justify the recent euphoria of public investment in infrastructure projects. After all, investing in infrastructure could well be the missing link in the economic policy, which according to the present findings can lead to a considerable increase in private sector's productivity.

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