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# Public infrastructure and productivity growth in Greek agriculture

E.C. Mamatzakis\*

*Council of Economic Advisors, Ministry of Economy and Finance, Nikis 5–7, Athens 101 80, Greece*

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## Abstract

Recent research has focused on the effect of public infrastructure on economic performance. In this paper, a model of Greek agriculture's technology and behaviour is constructed based on the dual cost function framework. The model provides a decomposition of productivity growth into the components technical change, returns to scale, and public infrastructure. The empirical estimates indicate that public infrastructure investment provides a significant return to agriculture and augments productivity growth. Over the period 1960–1995, the impact of public infrastructure on productivity growth in livestock and crop production is found to be positive, although it has been declining since the late 1970s. These results strongly suggest that a decline in public infrastructure investment can partly explain the observed decline in the productivity growth of Greek agriculture in the 1980s.

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## 1. Introduction

Undoubtedly, productivity growth has always been central in discussions of the development of agriculture. Jorgenson (1997) defines productivity growth as “*the part of output growth that cannot be explained by an increase in the use of inputs*”. Moreover, productivity growth is attributed to improvements in technology, scale effects and an increase in the efficiency of resource use (see Capalbo and Antle, 1988).<sup>1</sup> However, trying to measure productivity growth and identify all its determinant factors is a task that has generated much controversy. This is due to the fact

that there are many different methods of measuring productivity growth and a wide variety of determinant factors have been proposed.

Surprisingly, one rather neglected determinant of productivity growth is public infrastructure, though its importance has been unequivocal.<sup>2</sup> Over the last decade, however, a plethora of studies on the returns to investment in public infrastructure has emerged. Most have argued that public infrastructure positively affects economic performance, although it remains controversial to what extent (Aschauer, 1989; Munnel, 1990a,b; Ford and Poret, 1991). However, some studies (e.g. Evans and Karras, 1994) have challenged these findings by suggesting that the effect of public infrastructure is insignificant. And while the above

\* Tel.: +30-210-3332837; fax: +30-210-3332527.

E-mail address: [mmamatzakis@mnec.gr](mailto:mmamatzakis@mnec.gr) (E.C. Mamatzakis).

<sup>1</sup> It is frequently mistaken that productivity growth equals output growth. Growth is mainly explained by increases in factor productivity, and/or growth in input use.

<sup>2</sup> Griliches (1963) argues that “*the growth in agricultural productivity can be attributed in fairly equal proportions to input quality changes, economies of scale, and public investment*”.

studies employ a variety of data, most have adopted a similar methodology, based on the Cobb–Douglas production function, which has been criticised as too restrictive (Gramlich, 1994).

A sector of economic activity in which the role of public infrastructure may be seen as particularly influential is agriculture. In recent years, the EU and member states have heavily contributed to infrastructure investment in roads, dams, irrigation canals and ports. As a consequence, it would be of interest to justify public expenditure in infrastructure by measuring its impact on the productivity of the sector. The objective of this paper is to empirically assess the significance of public infrastructure investment for productivity growth of agriculture,<sup>3</sup> using an alternative and flexible theoretical framework which incorporates the underlying economic mechanism of cost minimisation. The main advantage of this approach is its ability to provide a quantitative measure of productivity growth that can be subsequently decomposed to isolate the contribution of public infrastructure without imposing the restrictions of a production function (Nadiri and Mamounas, 1994; Vijverberg et al., 1997). Vijverberg et al. (1997) present a comparative study of three different approaches (production function model, cost function model and profit function model) to investigate whether public capital is a major cause of declining labour productivity in the US economy. The authors argue that the cost function approach, in general, performs better than either the production function or profit function approach in line with previous research (Berndt and Hansson, 1992; Lynde and Richmond, 1992; Nadiri and Mamounas, 1994; Feltenstein and Ha, 1995; Morrison and Schwartz, 1994, 1996).

Earlier research indicates that public infrastructure may be one of the productive inputs for Greek agriculture (Fousekis and Pantzios, 2000). In agriculture, it is generally expected that the significance of the infrastructure impact will be strong since the sector heavily depends on roads, dams, etc. Therefore, infrastructure investment can significantly affect total factor pro-

ductivity (TFP), regardless of technical change and returns to scale effects. The implication is that even under conditions of no technical change and constant returns to scale, productive public infrastructure may enhance productivity growth.

The purpose of this paper is thus three-fold: (i) to look at the link between agricultural productivity and public infrastructure; (ii) to develop a theoretical and empirical model in which the impact of public infrastructure is separated from that of other factors by decomposing TFP into the effects of technical change, returns to scale and public infrastructure; and (iii) to apply this model to the case of Greek agriculture and derive policy implications.

The remainder of the paper is organised as follows: Section 2 presents the theoretical framework and empirical model, Section 3 discusses the dataset, the estimation procedure, and the main empirical findings, and Section 4 includes concluding remarks and economic policy implications derived from the empirical findings.

## **2. A theoretical specification and an empirical model**

In this study, the production inputs considered are: private capital, labour, intermediate inputs and public infrastructure. Subsequently, these inputs are classified into fixed and variable. Fousekis and Papakonstantinou (1997) treat only self-employed labour as a variable input, and the capital stock as fixed, while Mergos and Karagiannis (1997) treat the private capital stock as variable. Chambers and Pope (1994), in a study of US agriculture, assume that all inputs are variable, except for land. Here, private capital stock, labour and intermediate inputs enter the cost function as variable inputs, while the only exogenous input is public infrastructure, since no price is associated with its provision and it is not specified as part of the decision making process in agriculture.

The omission of land is due to the relatively constant amount of cultivated land in Greek agriculture over the last four decades,<sup>4</sup> indicating that if there was

<sup>3</sup> The impact of public infrastructure on the productivity growth of Greek agriculture has rarely been investigated in the past. Fousekis and Pantzios (2000) provide an initial look at the Greek experience by analysing the effect of public infrastructure on the economic performance.

<sup>4</sup> The annual rate of growth of land use fluctuated around 0.012% in the period 1960–1995. However, changes in the equality of land have occurred. Irrigated land expanded from 5203 acres in 1961 to 13,573 acres in 1995.

a change it was mainly qualitative. A way to account for these changes is to include in the series of capital stock, whether private or public, various land development schemes, such as irrigation canals (Fousekis and Papakonstantinou, 1997).

Assume that agricultural production depends on the services of the primary inputs private capital ( $K$ ) and labour ( $L$ ), intermediate inputs ( $M$ ), and public infrastructure ( $G$ ). Assume also that the services derived from public capital are provided free of charge. The implied dual total cost function can be written as:

$$C = C(P_L, P_K, P_M, G, Y_j, T), \quad (1)$$

where  $P_L$ ,  $P_K$  and  $P_M$  are the prices of labour, private capital stock, and intermediate inputs, respectively,  $Y_j$  a vector of outputs ( $j$  = crop, livestock),  $G$  the public infrastructure, and  $T$  a measure of technological change.

The economic intuition underlying the dual cost function approach rests on the main objective of the representative farmer, which is to minimise total cost given a level of outputs and the price of inputs (Mergos and Karagiannis, 1997).<sup>5</sup> Hence, the agricultural sector's problem is to minimise the total cost of production given a production function ( $F$ ):

$$C(P_i, G, Y_j, T) = \min_{x_i} \left\{ \sum_{i=1}^n P_i X_i : F(X_i, Y_j, G, T) = 0 \right\}, \quad (2)$$

where  $P_i$  are the prices of the private purchased inputs ( $i = K, L, M$ ). For the purposes of this study, the translog cost formulation introduced by Christensen et al. (1971) is used:

$$\begin{aligned} \ln C = & \alpha_0 + \sum_{i=1}^n \alpha_i \ln P_i + \sum_{j=1}^m \beta_j \ln Y_j + \alpha_G \ln G \\ & + \alpha_T T + \frac{1}{2} \sum_{i=1}^n \sum_{l=1}^n \alpha_{il} \ln P_i \ln P_l + \frac{1}{2} \alpha_{GG} (\ln G)^2 \\ & + \frac{1}{2} \sum_{j=1}^m \sum_{h=1}^m \beta_{jh} \ln Y_j \ln Y_h + \frac{1}{2} \alpha_{TT} T^2 \end{aligned}$$

<sup>5</sup> However, one might question whether output can be treated as an exogenous variable. In Section 2 of this study, instrumental variables are used to overcome endogeneity problems.

$$\begin{aligned} & + \sum_{i=1}^n \sum_{j=1}^m \gamma_{ij} \ln P_i \ln Y_j + \sum_{i=1}^n \gamma_{iT} \ln P_i T \\ & + \sum_{i=1}^n \gamma_{iG} \ln P_i \ln G + \sum_{j=1}^m \beta_{jT} \ln Y_j T \\ & + \sum_{j=1}^m \beta_{jG} \ln Y_j \ln G + \gamma_{GT} \ln GT, \end{aligned} \quad (3)$$

where it is assumed that  $\alpha_{il} = \alpha_{li}$ .

In order to be well behaved, Eq. (3) must exhibit homogeneity of degree one in the prices of private purchased inputs of production,  $P_L$ ,  $P_K$  and  $P_M$ :

$$\begin{aligned} \sum_{i=1}^n \alpha_i &= 1, \\ \text{and} \\ \sum_{i=1}^n \alpha_{il} &= \sum_{j=1}^m \gamma_{ij} = \sum_{i=1}^n \gamma_{iT} = \sum_{i=1}^n \gamma_{iG} = 0. \end{aligned} \quad (4)$$

Applying Shephard's Lemma, the cost-minimising shares for the private purchased inputs ( $L$ ,  $K$  and  $M$ ) can be derived as follows:

$$\begin{aligned} S_i &= \frac{\Delta \ln C}{\Delta \ln P_i} = \alpha_i + \gamma_{iT} T + \sum_{l=1}^n \alpha_{il} \ln P_l \\ &+ \sum_{j=1}^m \gamma_{ij} \ln Y_j + \gamma_{iG} \ln G, \end{aligned} \quad (5a)$$

while the elasticities of cost with respect to output and public infrastructure are:

$$\begin{aligned} R_j &= \frac{\Delta \ln C}{\Delta \ln Y_j} = \beta_j + \beta_{jT} T + \sum_{i=1}^n \gamma_{ij} \ln P_i \\ &+ \sum_{h=1}^m \beta_{jh} \ln Y_h + \beta_{jG} \ln G, \end{aligned} \quad (5b)$$

$$\begin{aligned} \eta_G &= \frac{\Delta \ln C}{\Delta \ln G} = \alpha_G + \gamma_{GT} T + \sum_{i=1}^n \gamma_{iG} \ln P_i \\ &+ \sum_{j=1}^m \beta_{jG} \ln Y_j + \alpha_{GG} \ln G. \end{aligned} \quad (5c)$$

Note, that Eq. (5c) is an expression of the 'shadow share' of public infrastructure and, hence, it is an

implicit measure of return to public capital (Morrison and Schwartz, 1996). If public infrastructure is productive, its ‘shadow share’ (5c) reflects the reduction in total costs due to a percentage change in public infrastructure.

Although it might be of interest to estimate the ‘productivity’ effects of public infrastructure through its shadow share, the importance of the cost function lies in its ability to measure productivity growth based on the parameter estimates of Eq. (2). Here, a transformation of the methodology proposed by Morrison and Schwartz (1996) is adopted to derive estimates of agricultural productivity growth as well as to decompose it. We therefore opt for a cost-side definition of productivity growth, letting dots above variables denote derivatives with respect to time:

$$\text{T}\dot{\text{F}}\text{P} = -\varepsilon_{CT} + \left( \sum_{j=1}^m \frac{\dot{Y}_j}{Y_j} - \sum_{j=1}^m \varepsilon_{CY_j} \frac{\dot{Y}_j}{Y_j} \right) + \eta_G \frac{\dot{G}}{G}. \quad (6)$$

Eq. (6) is a measure of productivity growth that decomposes the Solow residual, the ‘measure of our ignorance’, into the impacts of technical change, scale economies, and the contribution of public infrastructure. The technical change term is positive since costs decline with technical change (Morrison and Schwartz, 1996). The second term refers to returns to scale; if the term in parenthesis is negative, zero or positive, returns to scale are decreasing, constant or increasing, respectively. The third term on the right-hand side of (6) corresponds to the contribution of public infrastructure to productivity growth in Greek agriculture, reflecting the inclusion of public infrastructure as an unpaid input of production and departing from the traditional growth accounting techniques. A number greater than zero would imply that the impact of public infrastructure is positive. As a consequence, higher investment in infrastructure capital would enhance productivity growth.

### 3. Estimation procedure and results

The theory described in Section 2 is the basis for obtaining quantitative estimates of the impact of pub-

lic infrastructure on cost and productivity growth in Greek agriculture. Taking into account the criticism of implausibly high returns to public infrastructure at an aggregate level of the national economy (see Munnel, 1990b; Holtz-Eakin, 1994; Morrison and Schwartz, 1996), Greek agricultural output is disaggregated into crop and livestock products. The data is annual and covers the period 1960–1995 (see Appendices A and B). We define public infrastructure as core infrastructure in line with Diewert (1986). Core infrastructure embodies services derived from public capital stock in ports, railways, motor vehicles and roads, as well as electrical and communication facilities. For the purposes of the present study, ‘core infrastructure’ has been augmented by land improvement projects, such as irrigation canals, that are particularly beneficial to agriculture. Note that this definition is in line with the one adopted by Conrad and Seitz (1994) and Nadiri and Mamouneas (1994), and covers public infrastructure capital that produces services that directly enter the private production process. Public infrastructure is perceived to be a non-marketable good; this implies that no price is charged for its services. Hence, in the present analysis, public infrastructure is treated as an unpaid input along the line of previous research in the area (Lynde and Richmond, 1992; Nadiri and Mamouneas, 1994; Morrison and Schwartz, 1994; Fousekis and Pantzios, 2000).

The three-stage least squares (3SLS) estimation procedure is followed. The total cost function, intermediate input demand and labour demand comprise the system of equations to be estimated. However, 3SLS estimation is sensitive to which cost share equation is excluded to ensure homogeneity of degree 1. To overcome this problem, we apply iterated 3SLS (I3SLS), which ensures that the parameter estimates of the system are invariant to the choice of the excluded cost share equation (Judge, 1980). In addition, this estimation method employs lagged values of the annual series as instruments, and thus deals with possible simultaneity bias and endogeneity issues. Imposing optimisation behaviour in Greek agriculture, linear homogeneity and symmetry further enhances the overall efficiency of I3SLS.

Table 1 reports the estimated parameters of the system of equations. Overall, the results suggest that the estimated translog cost function for Greek agriculture

Table 1  
Estimates of the translog cost function for Greek agriculture

Parameter	Estimate	<i>t</i> -Statistics
$\alpha_0$	3.129	2.37
$\alpha_M$	0.392	4.65
$\alpha_L$	0.382	7.88
$\beta_1$	0.42	3.02
$\beta_2$	0.51	2.54
$\beta_{11}$	1.61	2.08
$\beta_{22}$	−1.45	−2.48
$\beta_{12}$	−0.443	−1.05
$\alpha_{MM}$	−0.356	−6.05
$\alpha_{LL}$	0.080	3.32
$\alpha_{ML}$	−0.152	−3.15
$\gamma_{L1}$	−0.157	−3.56
$\gamma_{L2}$	−0.023	−1.26
$\gamma_{M1}$	0.466	6.08
$\gamma_{M2}$	0.417	2.57
$\alpha_G$	−0.103	−2.16
$\alpha_{GG}$	−0.731	−2.11
$\gamma_{MG}$	0.002	2.11
$\gamma_{LG}$	−0.012	−1.56
$\beta_{G1}$	−2.299	−3.13
$\beta_{G2}$	−0.407	−0.39
$\alpha_T$	−0.396	−2.85
$\alpha_{TT}$	−0.010	−1.74
$\gamma_{LT}$	−0.007	−1.54
$\gamma_{MT}$	−0.002	−0.43
$\gamma_{GT}$	0.189	3.82
$\beta_{T1}$	0.333	1.46
$\beta_{T2}$	−0.027	−2.13
$\alpha_K$	0.225	3.10
$\gamma_{KL}$	0.072	3.03
$\gamma_{KM}$	−0.203	−5.02
$\beta_{KK}$	0.130	3.84
$\gamma_{K1}$	−0.309	−4.45
$\gamma_{K2}$	−0.394	−3.01
$\gamma_{KG}$	0.010	1.62
$\gamma_{KT}$	0.009	1.85

Translog cost function:  $R^2 = 0.99$ ; S.E. = 0.09; DW = 2.11.  
Labour:  $R^2 = 0.98$ ; S.E. = 0.01; DW = 1.78. Intermediate inputs:  
 $R^2 = 0.98$ ; S.E. = 0.02; DW = 1.83. Source: own calculations.

principal minors are equal to 2.353 and 3.44).<sup>6</sup> In addition, the implied own mean price elasticities are −0.28, −0.55 and −1.23 for intermediate inputs, labour and private capital, respectively. The mean elasticity of cost with respect to crop and livestock are 0.523 and 0.289, respectively. These elasticities imply that an increase in crop output will proportionally raise cost more than an equal increase in the production of livestock. In detail, Table 1 further shows that the reported parameter estimates justify the underlying conditions and restrictions, and  $\alpha_K$ ,  $\alpha_L$  and  $\alpha_M$  are positive and significant.<sup>7</sup>

In addition, it is plausible to expect that the total cost function is non-increasing in public infrastructure, which enters the cost function as an exogenous input. That is, an increase in public infrastructure should not increase the cost of agricultural production. Table 1 reports that the average value share of public infrastructure ( $\alpha_G$ ) has a negative sign, is significant and compares in magnitude with other studies (see Lynde and Richmond, 1992; Nadiri and Mamouneas, 1994; Morrison and Schwartz, 1994). Based on this estimate, one might argue that public infrastructure exhibits a positive spill-over effect on economic performance of Greek agriculture. However, more evidence in the form of the shadow share of public infrastructure and its impact on

<sup>6</sup> These figures are calculated at the sample means. The condition of monotonicity is satisfied at the point of approximation, where  $P_i$  ( $i = K, L, M$ ),  $G$  and  $Y_j$  ( $j = \text{crop, livestock}$ ) are indexed to one and  $T$  is indexed to zero. Strict monotonicity is satisfied at other sample points since the fitted shares for labour, capital and intermediate inputs are all positive. In addition, for strict quasi-concavity, the  $3 \times 3$  matrix of substitution elasticities must be negative semidefinite at each observation. In order to test for strict quasi-concavity, we proceed with the eigenvalues of the above matrix and its LDL factorisation using TSP 4.4. The results show that the cost function is concave in input prices at all the sample points except the years 1987 and 1988. For these years, concavity in variable inputs is imposed.

<sup>7</sup> The generalised  $\bar{R}^2 = 0.987$ , implying that the goodness of fit of the system of equations is adequate. The Jarque–Berra statistic for normality of the residuals is 0.24 (0.9) for the cost equation, 1.14 (0.65) for the labour equation, and 0.4 (0.73) for the intermediate equation. In all cases, the null hypothesis of normality is not rejected. In addition, DW statistics indicate that serial correlation is not present. Note that the use of I3SLS ensures that the estimated parameters approximately approach those obtained using full information maximum likelihood, which is the preferred technique if serial correlation is present (Vijverberg et al., 1997).

is well behaved. The signs on the coefficients of the cost function are found to be consistent with curvature conditions, while the magnitudes of the estimated elasticities are plausible and statistically significant. Moreover, the estimated cost function is found to be concave in input prices (as the determinants of the principal minors of the Hessian matrix are equal to −0.194, −0.409 and −1.56) and convex in output quantities (as the corresponding determinants of the

productivity growth is required to support definitive conclusions.

The parameters  $\gamma_{LG}$ ,  $\gamma_{KG}$  and  $\gamma_{MG}$  in Table 1 capture the spill-over effect of public infrastructure on private purchased inputs. More precisely, these parameters measure the ‘factor bias effect’ of public infrastructure on the cost shares of labour, private capital stock and intermediate inputs. Based on the estimates in Table 1, public infrastructure has a positive spill-over effect on intermediate inputs and private capital (though not significant), while the opposite spill-over effect obtains for labour.

The estimates of  $\beta_{G1}$  and  $\beta_{G2}$  can be interpreted as the responses of marginal cost to changes in public infrastructure. Specifically, the signs and the magnitudes of these parameters indicate whether public infrastructure increases or reduces marginal costs in crop and livestock production, respectively. The estimated parameters show that public infrastructure reduces marginal costs, though in the case of the livestock production the effect is insignificant.

The technical change biases are estimated by  $\gamma_{KT}$ ,  $\gamma_{LT}$ ,  $\gamma_{MT}$  and  $\gamma_{GT}$ . These parameters indicate changes of the  $i$ th input’s share in total cost over time. Table 1 shows that the shares of labour and intermediate inputs in total cost have fallen over time, while the shares of private and public capital stock have increased. This result does not come as a surprise, since new technologies in have tended to be capital intensive. Similarly, public infrastructure has become increasingly important over time, especially in the EU, where transportation to and from remote markets, and the standardisation of agricultural products can be supported by public investment in infrastructure projects.

### 3.1. Shadow share of public infrastructure

Table 2 reports the cost elasticity of public infrastructure, which is the parameter estimate of the ‘shadow share’ of public infrastructure ( $\eta_G$ ) capturing the spill-over effect of public infrastructure on cost of our sample of agriculture. A negative (positive) sign would imply that public infrastructure is a cost-reducing (cost-increasing) factor of production. Hence, if the estimated elasticity is zero or positive, then it would be clearly advisable for the government to curtail expenditure on public infrastructure. On the other hand, a negative estimated relationship between

Table 2

The cost elasticity of public infrastructure

Period	$\eta_G$
1961–1969	–0.349 (0.097)
1970–1979	–0.274 (0.134)
1980–1989	–0.083 (0.027)
1990–1995	–0.746 (0.238)
1961–1995	–0.382 (0.087)

Standard errors in parentheses. *Source:* own calculations.

public infrastructure and agriculture cost would imply that reduced provision of public infrastructure, due to lower levels of public investment (see Mergos and Karagiannis, 1997), could offer an alternative explanation of the reported slow productivity growth in the 1970s and 1980s.

Here, the evidence suggests that the impact of public infrastructure on costs is negative over the whole sample period. Over the entire period from 1961 to 1995, a 1% increase in public infrastructure reduced the cost of livestock and crop production by 0.38%. In similar way, enhancing public infrastructure could lead to a downward shift in the average cost curves of livestock and crop production and, hence, increase the competitiveness of Greek agriculture. Fousekis and Pantzios (2000), using a profit function and holding output constant, report a cost elasticity of public infrastructure of –0.26. This estimate is comparable with ours and it is in line with other results in the literature (Berndt and Hansson, 1992; Lynde and Richmond, 1992; Nadiri and Mamounas, 1994; Morrison and Schwartz, 1994; Feltenstein and Ha, 1995).

Note, however, that the cost elasticity of public infrastructure declines over the years, especially during the 1980s. This is not surprising since gross public fixed capital formation rapidly deteriorated in the 1970s and 1980s, reducing the productivity performance of agriculture. A slow-down in public infrastructure investment may thus explain the reported decline of the average productivity effect of infrastructure reported in Table 2.

Fig. 1 shows that public investment started to decline in the early 1970s, a period in which Greek agriculture also exhibited signs of low performance (Mergos, 1993). Moreover, Mundlak (1988) points out that the rate of change in output is closely related to the level of agricultural investment. Hence, the observed decline in the Greek agricultural investment



Fig. 1. Public and private investment in Greek agriculture (constant prices, in million Drachmas). *Source:* Agriculture Bank of Greece, "Economic Accounts".

(both private and public) could constitute one of the main explanations for the slow-down in Greek agriculture. However, since early in the 1990s, this process has reversed and private investment shows signs of reviving, while public investment has increased, mainly due to funding from the EU. As a result, the productivity impact of public infrastructure increases to over 0.7% in the early 1990s.

A decomposition of public investment in agriculture reveals a bias for certain projects. More than 70% of this investment focused on expanding cultivated land under irrigation. Irrigated land expanded from 0.5 to 1.25 million hectares between 1960 and early 1990s. Although irrigated land contributes positively to the expansion of output, especially that of crops, the large government bias in favour of irrigation neglected other forms of public capital formation, such as rural transportation and establishment of regional markets and export orientated centres. Moreover, the

empirical findings dramatically portray the decline in the cost-reducing effect of public infrastructure from 0.34% in the 1960s to 0.27 and 0.08% in the 1970s and 1980s, respectively. This measure clearly argues that the well-documented poor performance of Greek agriculture in the 1970s and 1980s can be partly explained by the low infrastructure investment of that period (see Mergos and Karagiannis, 1997; Fousekis and Papakonstantinou, 1997).

In the 1990s, the need for enhancing fixed capital formation was acknowledged both in Greece and by the EU Commission. One area which the EU has particularly emphasised is the creation and modernisation of so-called 'core infrastructure'. As a result, investment in public infrastructure has dramatically increased since early in the 1990s mainly due to EU financial resources. The EU Community Support Framework for Greece amounted to more than 3.7% of annual Greek GDP for the period 1990–2000,



and of this amount 28% have been allocated to big infrastructure projects such as ports, railways, communications, energy and irrigation. These investment projects have resulted in an increase of the productivity impact of public infrastructure in the early 1990s.

Apart from the aforementioned productivity effect of public infrastructure, the total impact of public infrastructure on private purchased inputs can also be derived. The reported factor bias effect of public infrastructure in Table 1 suggests that public infrastructure is a complement to intermediate inputs and private capital stock, and a substitute for labour. However, while these factor bias effects serve as an indication of the true relationship between public infrastructure and private purchased inputs, they are incomplete measures, mainly because they do not take into account the productivity impact of public infrastructure on those inputs. A complete picture of the total impact of public infrastructure on private purchased inputs is given by:

$$\eta_{iG} = \eta_G + \frac{\gamma_{iG}}{S_i}, \quad i = K, L, M, \quad (7)$$

which is the sum of the ‘productivity’ and ‘factor bias effects’ of public infrastructure divided by the share of *i*th input in total cost (Nadiri and Mamounes, 1994). The sign of  $\eta_{iG}$  depends on productivity and factor bias components which can either reinforce or offset each other.  $\eta_{iG} > 0$  ( $< 0$ ) implies that as the public capital stock increases, a factor using (saving) effect on input *i* occurs.

Table 3 presents the estimates of the mean total impact of public infrastructure on private purchased inputs in livestock and crop production. Over the whole sample period (1961–1995), public infrastructure is a complement to private capital stock and intermediate inputs, while the opposite is true for labour. This is an interesting result, as it implies that public infrastructure favours production processes that are cap-

Table 3  
Input demand elasticities

Period	$\eta_{KG}$	$\eta_{LG}$	$\eta_{MG}$
1961–1969	0.321 (0.170)	−0.389 (0.091)	0.343 (0.17)
1970–1979	0.061 (0.072)	−0.143 (0.013)	0.097 (0.061)
1980–1989	0.025 (0.09)	−0.161 (0.063)	0.051 (0.013)
1961–1995	0.351 (0.068)	−0.464 (0.11)	0.378 (0.21)

Standard errors in parentheses. *Source*: own calculations.

Table 4

The effects of public infrastructure on the productivity growth of Greek agriculture

Period	Rate of technical change	Scale effect	Public infrastructure effect	TFP <sup>a</sup>
1961–1969	0.095	0.906	2.335	3.337
1970–1979	0.091	1.276	1.337	2.704
1980–1989	0.135	0.748	0.174	1.057
1961–1980	0.090	1.221	1.944	3.256
1981–1995	0.114	0.007	1.484	1.607
1961–1995	0.104	0.790	1.852	2.674

*Source*: own calculations.

<sup>a</sup> TFP is the sum of the rate of the technical change, scale and public infrastructure effects.

ital and intermediate inputs intensive as opposed to traditional labour intensive production, thus supporting the modernisation and mechanisation of Greek agriculture.

### 3.2. Productivity growth and public infrastructure

Earlier findings by Mergos and Karagiannis (1997) and Fousekis and Papakonstantinou (1997) have identified a slow-down in the productivity growth of Greek agriculture in the 1970s and 1980s.<sup>8</sup> Fousekis and Papakonstantinou (1997) emphasise the importance of two factors as potential explanations for this slow-down: (a) the increase in the rate of capital utilisation since the early 1980s that has resulted in higher marginal production costs and thus lower productivity growth; and (b) the shift of Greek agriculture into new crops. Mergos and Karagiannis (1997) point out the importance of the fixity of inputs and the resulting disequilibrium, while Fousekis and Pantzios (2000) report that public infrastructure is positively correlated with the TFP of Greek agriculture.

The results of this study substantiate the negative impact of the decline of infrastructure investment on productivity growth over the last three decades. An exact decomposition of the TFP growth rate in Greek agriculture is reported in Table 4 for the period 1961–1995. In this table, the growth rate of TFP is decomposed into: (a) the rate of technical change; (b)

<sup>8</sup> Mergos and Karagiannis find that agricultural productivity growth fell from 3.42% in the period 1961–1969 to 1.74% in the period 1981–1993.

scale effect; and (c) the public infrastructure effect.<sup>9</sup> These measures can be interpreted as percentage changes.<sup>10</sup> Clearly, productivity growth exhibited a decline since the early 1970s, falling further in the 1980s to its lowest level of 1.06%. Moreover, TFP growth declined from 3.26% in the period 1961–1980 to 1.61% in the period 1981–1995. These results are in line with previous empirical findings (Mergos and Karagiannis, 1997; Fousekis and Papakonstantinou, 1997; Fousekis and Pantzios, 2000).

Greece endured significant political and economic upheavals over the period 1960–1995. The contribution of public infrastructure to productivity growth over this period was positive, albeit declining in the 1970s and 1980s. According to the results in Table 4, the impact of public infrastructure was quite substantial in magnitude (2.34%) in the 1960s. During this period, Greece was able to attract substantial foreign investment and thus exhibit strong growth by sustaining macroeconomic stability. This positive economic development is reflected in the reported strong (3.4%) productivity growth in agriculture in the 1960s. However, economic policies in the 1970s and 1980s did not favour investment in agriculture in general and in infrastructure in particular, and as a result the strong productivity growth pattern reversed. Moreover, in these decades macroeconomic instability raised the interest rates for farmer's borrowing and thus increased the unit cost of capital, directing valuable savings for the development of the economy away from productive investment. In parallel, infrastructure investment was curtailed as a measure to restrain fiscal imbalances. As the results in Table 4 demonstrate, the contribution of public infrastructure dramatically declined to 1.34% in the 1970s and to 0.17% in the 1980s. Hence,

these decades were characterised by under-investment by the public sector that crippled the productivity performance of agriculture.

Over the whole period, technical change and scale effects have also contributed to productivity growth, although the impact of scale economies fell from 1.27% in the 1970s to 0.74% in the 1980s. The impact of technological change is of particular interest, as it is reported to increase from 0.09% in the 1970s to 0.14% in the 1980s. In the latter period, productivity growth was slow at 1.06%, with only technical change reporting an increase in its contribution to TFP. Hence, the progressive technological change reported in the 1980s appears to have partially compensated for the diminishing contributions of public infrastructure and scale economies.

The evidence reported above indicates that the TFP slow-down is closely related to the decline in the contribution of the public infrastructure effect on productivity growth. Fading infrastructure investment in the 1970s and 1980s undermined the growth prospects of the agricultural sector. These results clearly emphasise that increased investment in public infrastructure may well constitute one of the key factors that policy makers can utilise to invigorate Greek agriculture, a sector currently in decline.

It is, however, worth mentioning that although infrastructure investment is found to enhance economic performance, one should also take into account the cost of financing such investment. The use of government or EU money to build infrastructure projects may have distorting effects through taxation that should be carefully considered in discussions of raising infrastructure investment. One should also consider the possible private provision of infrastructure services. However, in the absence of private provision of these services, economic policies that oversee the importance of infrastructure investment reduce the potential for growth.

#### 4. Conclusions

It has been frequently quoted in the literature (OECD, 1995) that one decisive cause of the observed slow-down in agricultural productivity growth might reduced public investment. The present study provides evidence of the positive contribution of public

<sup>9</sup> The hypotheses of constant returns to scale, zero-rate technical change and zero-rate infrastructure effect are rejected, indicating the statistical significance of scale, technical change and infrastructure effects on TFP growth. For the case of constant returns to scale, the calculated chi-squared statistic (d.f. = 5; Wald test) is 156.7, in the case of no technical change the corresponding figure is 233.7, and in the case of infrastructure effects the test statistic is 187.3.

<sup>10</sup> The magnitude of the impact of public infrastructure depends on the growth rate of public capital stock ( $\dot{G}/G$ ) and the value of the 'shadow share' of public infrastructure ( $\eta_G$ ). Notice that the contribution of public infrastructure to productivity growth may be small, even in the case of a high  $\eta_G$ , if  $\dot{G}$  is small compared with  $G$ .

infrastructure on productivity growth in Greek agriculture over the last three decades. A decomposition of TFP shows that infrastructure investment may well be responsible for the slow-down in the 1980s. This suggests that productivity growth cannot be attributed to technical change and scale economies alone.

This paper develops a comprehensive theoretical framework which permits the decomposition of long run productivity growth to the components technical change, returns to scale, and public infrastructure. Overall, is shown that public infrastructure reduces the total cost of Greek agriculture and thus can be regarded as a productive input that contributes to productivity growth. Specifically, a 1% increase in public infrastructure investment is found to reduce the total cost of livestock and crop production by 0.38%. Hence, the decline in public infrastructure investment in the 1970s and 1980s is found to adversely affect the productivity performance of Greek agriculture. This suggests that infrastructure investment may serve as a means of stimulating long-term growth.

Only recently, in the mid-1990s, has the trend of a declining capital stock been reversed. Undoubtedly, EU policies have supported the expansion of the capital stock in Greece. Recent reforms of the EU's Common Agriculture Policy have gradually restricted direct forms of intervention using traditional and popular tools such as subsidies. The findings of this study point to new policy channels that might be used to lift the competitiveness of Greek agriculture. The empirical evidence presented here shows that public infrastructure is capable of enhancing productivity growth and inducing changes in the production process in favour of capital and intermediate intensive production. Essentially, infrastructure investment may form an economic policy instrument that can lead the economy to higher development patterns. It is not by chance that the EU support framework for Greece gives priority to the creation of appropriate infrastructure as a necessary condition for real convergence with the most developed member states of the EU.

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## Appendix A. Deriving a parametric measure of productivity growth

The dual productivity growth measure can be found by substituting the derivative of cost:  $dC/dT = \sum_{i=1}^n P_i(dX_i/dT) + \sum_{i=1}^n X_i(dP_i/dT)$ , where  $C = \sum_{i=1}^n P_i X_i$  ( $i = K, L, M$ ), into the total derivative of the cost function  $C = C(P_i, Y_j, T)$  with respect to  $T$  (see Ohta, 1974). The resulting dual measure of productivity growth is:

$$-\varepsilon_{CT} = -\frac{\dot{C}}{C} + \sum_{j=1}^m \varepsilon_{CY_j} \frac{\dot{Y}_j}{Y_j} + \sum_{i=1}^n S_i \frac{\dot{P}_i}{P_i}, \quad (\text{A.1})$$

where  $S_i$  is the share of  $i$ th input in total cost ( $C$ ),  $\varepsilon_{CY_j}$  the partial derivative of the cost function with respect to output  $j$  ( $j = \text{crop, livestock}$ ), and dots above variables indicate derivatives with respect to time.  $-\varepsilon_{CT}$  is expected to be positive since total costs decline with technical change.

Equivalently, the primal measure of productivity growth is:

$$-\varepsilon_{CT} = \sum_{j=1}^m \varepsilon_{CY_j} \frac{\dot{Y}_j}{Y_j} - \sum_{i=1}^n S_i \frac{\dot{X}_i}{X_i}. \quad (\text{A.2})$$

Note that the hypothesis of constant returns to scale ( $\varepsilon_{CY_j} = 1$ ) is rather restrictive. Previous empirical research (e.g. Mergos and Karagiannis, 1997) shows that this hypothesis is not valid. In the event that  $\varepsilon_{CY_j} = 1$ , Eq. (A.2) reduces to the traditional primal index number expression for total productivity growth (TFP) (Morrison and Schwartz, 1996):

$$\text{TFP} = \sum_{j=1}^m \frac{\dot{Y}_j}{Y_j} - \sum_{i=1}^n S_i \frac{\dot{X}_i}{X_i}. \quad (\text{A.3})$$

The introduction of public infrastructure, as a fixed and unpaid input, necessitates the transformation of Eqs. (A.1) and (A.2) as:

$$-\varepsilon_{CT} = \sum_{j=1}^m \varepsilon_{CY_j} \frac{\dot{Y}_j}{Y_j} - \sum_{i=1}^n S_i \frac{\dot{X}_i}{X_i} - \eta_G \frac{\dot{G}}{G}, \quad (\text{A.4})$$

where  $\eta_G = -d(\ln C)/d(\ln G)$  is the ‘shadow share’ of public infrastructure.

Eq. (A.4) represents the corrected ‘technical change’ measure, which recognises the individual contributions of private purchased inputs and public infrastructure to productivity growth. Combining Eqs. (A.2) and (A.4) gives the measure of productivity growth in Eq. (6).

## Appendix B. The dataset

In the following list, definitions and the sources of the dataset are provided. The dataset is annual and covers the period from 1960 to 1995:

- Output ( $Y$ ): Divisia indices of two outputs are used: (a) crop; and (b) livestock. Crop production includes cereals, pulses, vegetables, vines, fresh and dry fruits, olive oil and olives, vegetables and industrial crops. Meat, milk and eggs make up livestock output. Output prices are the average annual weighted prices of the selected agricultural products from different geographical regions and seasons. The data on output prices and quantities have been obtained from the Department of Prices and Cost of Agricultural Products, Ministry of Agriculture. These data are the same as those used by Mergos and Karagiannis (1997) to estimate TFP for Greek agriculture in a temporary equilibrium framework.
- Labour ( $L$ ): Data on employment is derived from ESYE, National Statistical Office of Greece, “Annual Employment Survey”. Labour input includes both self-employed (family) and hired labour. Labour cost ( $P_L$ ) is defined as the sum of the wage bill paid to hire workers and the imputed value of family labour. The imputed value of family labour is calculated as the opportunity cost of self-employment, which is assumed to be equal to the daily wage of hired workers (Mergos and Karagiannis, 1997). To account for underemployment and part-time employment of the agricultural labour force, labour was calculated as the number of working days per year, which declined over the period. Annual series on the wage bill paid to hired workers are obtained from the Department of Prices and Cost of Agricultural Products, Ministry of Agriculture.
- Intermediate inputs ( $M$ ): Intermediate inputs include seeds, energy and lubricants, fertilisers, plant production products, feedstuffs, agricultural tools and supplies, and maintenance and repair of machinery. An implicit price index of intermediate inputs ( $P_M$ ) is obtained by dividing current by constant expenditures. These time series are obtained from ESYE, National Statistical Office of Greece, “National Accounts”.
- Capital ( $K$ ): Time series on gross expenditures for capital goods augmented by land development projects are derived from Skoutzos and Matheos (1990) for the period 1960–1990 and the Ministry of Economy and Finance (1998) for the period 1990–1995. Moreover, gross expenditure on buildings, construction, machinery, equipment and land development projects were collected. Subsequently, the capital stock is estimated using the perpetual inventory method. The stock of capital is equal to a weighted sum of all past investment, where the asset’s usefulness is used as a weight. The usefulness of an asset is assumed to decline monotonically with age and is approximated by a rectangular hyperbola, where the curvature parameter describes the form of depreciation. The depreciation of machinery and equipment is supposed to occur over a large portion of the service life and with less severity than the depreciation of buildings. Hence, the value of the curvature parameter is assumed to be 0.75, 0.6 and 0.5 for buildings, construction and machinery, respectively. The mean service lives of buildings, construction and machinery are assumed to be 38, 20 and 9 years, respectively.
- Price of capital ( $P_K$ ): This price is defined as  $P_{KT} = i_T(r_T + \delta_T)$ , where  $i_T$  is the price per unit of investment or the investment deflator,  $r_T$  the rate of return to private capital stock, which is proxied by the ‘long-term’ nominal interest rate in agriculture, representing the opportunity cost of the last Drachma on investment, and  $\delta_T$  the rate of economic depreciation. Lynde and Richmond (1992) and Berndt and Hansson (1992) employ a similar measure of the price of capital. The annual series have been collected from ESYE, National Statistical Office of Greece, “National Accounts”.
- Public infrastructure ( $G$ ): The time series of net public capital stock are obtained from the Skoutzos and Matheos (1990) for the period 1950–1990 and from

the Ministry of Finance for the period 1990–1995. The stock of public capital is estimated using the perpetual inventory method as in the case of private capital stock.

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