Efficiency, Productivity and Output Growth: An Inter-Regional Analysis of Greek Agriculture

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Olive oil has traditionally been a *major* food crop in Greek agriculture. It accounts for approximately 10 per cent of total agricultural production and 12.5 per cent of Greek GDP. Average annual olive oil production during the period 1969–95 was 270 million tonnes, which represents almost 18 per cent of the world total. 52 per cent of total Greek farms benefit from olive tree cultivation, while 47 per cent of gross agricultural income is derived exclusively from olive oil. Production is concentrated in the central and southern regions of the country where climatic and soil conditions favour olive tree cultivation (Peloponnisos 35.2 per cent, Crete 31.2 per cent, Sterea Ellada 10.2 per cent). Almost all olive trees are grown on compact plantations, with nearly two-thirds located in mountainous and semi-mountainous areas. Olive farms are characterised by their small size and extensive fragmentation. The average farm is 15.5 stremmas (one stremma equals 1,000 m^2), fragmented into 6 plots in considerable distance from each other.

Since Greece's accession to the European Union (EU) in 1981, the olive-oil sector has undergone a series of substantial changes through the operation of the Common Agricultural Policy (CAP). Market intervention has occurred through price supports (on the market organization of olive oil and oilseeds see EC, 1997). The price support mechanism resulted in structural changes (i.e., increase in the number of farms and total area devoted to olive-tree cultivation), and a significant and persistent increase in olive-oil production.

The latest CAP reform, motivated by stipulations of the GATT agreement and the significant budgetary costs of farm programs, indicates a tendency towards a drastic reduction of price supports and production grants. The socio-economic significance of the olive oil sector calls for substitutes to declining farm income supports. Within the framework of fiscal austerity and liberal trade, making agriculture more competitive and market oriented could be a reasonable objective for Greek agricultural policy in forthcoming years.

In this context, knowledge of the relative contributions of total factor productivity (TFP) and input use to output growth in the three main olive oil production regions of the country would provide a comprehensive view of the structure of the olive oil sector, and could help farm managers and policy makers in Greece to ascertain appropriate policy measures in a regional context. The theoretical part of the present study relies on Bauer's (1990) decomposition analysis in the presence of both technical and allocative inefficiencies, economies of scale, and technical change, which is adjusted accordingly into an output growth formulation. The empirical analysis is based on the stochastic production frontier model developed by Bravo-Ureta and Rieger (1991) and Bravo-Ureta and Evenson (1994), which allows separate estimates of technical, allocative and economic efficiency. This approach is extended to the case of panel data and feasible GLS estimation to derive efficiency measures free of distributional assumptions. Moreover, the more flexible quasi-translog production frontier is utilized.

Empirical Model and Data

Modeling Economic Efficiency

A general random effects quasi-translog production frontier model may be specified as:

(1) $$\ln y_{it} = \beta_i + (\beta_t + \beta_{tt} t)t + \sum_{j=1}^{J} (\beta_j + \beta_{jt} t) \ln x_{jit} + v_{it}$$

where the subscript *it* denotes farm i at year t; y_{it} is the quantity produced; x_{jit} represents input *j*; *t* is a time variable reflecting technical change; *b* are estimated parameters; v_{it} is an *iid* zero mean random variable; and $\beta_i = \overline{\beta} - u_i$ are individual farm effects. The farm effects are independent random variables with mean $\overline{\beta}$ and variance σ_u^2, where u_i is an *iid* uncorrelated with v_{it}. This functional specification imposes separability between inputs but not between inputs and technological change. Even though it reduces to a Cobb-Douglas form in any particular year, its' production elasticities and returns to scale vary with time.

Following Cornwell *et al*., Bravo-Ureta and Rieger, and Bravo-Ureta and Evenson, farm and time specific technical efficiencies can be computed by dividing the technically efficient input vector over the actual input levels after weighting them with the relevant input prices.[1] For the estimation of allocative and economic efficiencies, the dual cost function corresponding to (1) is derived first. Since the production function in (1) is self-dual, a closed form solution of the cost minimization problem yields the following dual cost frontier (see Karagiannis *et al*.):

$$\text{(2)} \qquad \ln C_{it} = B + (\delta_t + \delta_{tt} t)t + \delta_y \ln y_{it} + \sum_{j=1}^{J} (\delta_j + \delta_{jt} t) \ln w_{jit}$$

where C_{it} is the minimum cost of production adjusted for statistical noise, and w_{jit} is the price of input *j*. B equals $\frac{1}{\delta_y^2}\left(\frac{1}{\delta_k + \delta_{kt} t}\right) - \sum_{j=1}^{J-1} \ln\left(\frac{\delta_j + \delta_{jt} t}{\delta_k + \delta_{kt} t}\right)(\delta_j + \delta_{jt} t) - \delta_0$ where $k \neq j \; \forall k$, while the parameters δ are derived from the production frontier estimates as:

$\delta_t = \beta_t \delta_y$, $\delta_{tt} = \beta_{tt} \delta_y$, $\delta_j = \beta_j \delta_y$, $\delta_{jt} = \beta_{jt} \delta_y$, $\delta_y = 1 \Big/ \sum_{j=1}^{J} (\beta_j + \beta_{jt} t)$, $\delta_0 = \delta_y \ln \beta_0$. Utilizing *Shephard's Lemma*, we obtain a system of factor demand equations, a closed solution of which provides the economically efficient input levels, x_{jit}^E. Farm and time specific measures of economic efficiency can be derived by dividing x_{jit}^E by the (weighted) actual input levels. Finally, the ratio of economic over technical efficiency provides the allocative efficiency of farm *i* at time *t* (Farrell).

[1] For a given output, farm specific technical efficient input levels are obtained by simultaneously solving a system comprised of the production frontier and the observed input ratios at the same level of output.

Accounting for Total Production Growth

Following Karagiannis *et al*. a relationship for output growth decomposition in a primal framework can be written as:

$$(3) \qquad \dot{y} = \sum_{j=1}^{J} s_j \dot{x}_j + \left(1 - \frac{1}{E}\right) \sum_{j=1}^{J} \varepsilon_j \dot{x}_j + T(x;t) + \dot{T} + \dot{A} + \sum_{j=1}^{J} \left[s_j - s_j(y, w; t) \right] \dot{w}_j$$

where a dot over a variable denotes growth over time; $s_j = w_j x_j / C$; $s_j(y, w; t) = \partial \ln C / \partial \ln w_j$;

$E = \sum_{j=1}^{J} \varepsilon_j = \sum_{j=1}^{J} \left(\partial \ln y / \partial \ln x_j\right)$ are the returns to scale estimated as the sum of the relevant production elasticities; T and A are input-based measures of technical and allocative efficiencies; and $T(x;t) = \partial \ln y / \partial t$ is the rate of technical change. All other variables are as previously defined.

The *first* term in (3) captures the contribution of input growth on output changes (size effect).[2] The *second* term measures the relative contribution of scale economies on output growth (scale effect). This term vanishes under constant returns to scale, while it is positive (negative) under increasing (decreasing) returns to scale as long as aggregate input increases. In measuring the contribution of the scale effect, estimated production elasticities are used instead of observed factor cost shares to allow for possible technical and allocative inefficiencies. The *third* term captures the impact of technical change through its influence on the coefficients of production.[3] The *fourth* and the *fifth* terms are measures of technical and allocative efficiency, respectively, and are positive (negative) as efficiency increases (decreases) over time. The *last* term in (3) is the price adjustment effect. This term indicates that the aggregate measure of inputs is biased in the presence of allocative efficiency (Bauer). The price adjustment effect is inversely related to the degree of allocative efficiency. Under

[2] Aggregate input growth is measured as a Divisia index. The fact that actual factor cost shares are used as weights of individual input growth gives rise to the sixth term in (3).
[3] Technical change is treated as disembodied and consists of two counterparts: an autonomous and a biased one. The

allocative efficiency, $s_j = s_j(y, w; t)$, this effect equals to zero. The price adjustment effect is also zero when input prices change at the same rate, since $\sum \left[s_j - s_j(y, w; t) \right] = 0$.

It is important to mention that none of the effects explaining output growth are measured on a residual basis. The unexplained residuals account for subequilibrium effects associated with the existence of quasi-fixed inputs and capacity under-utilization, learning-by-doing effects, cost of adjustment etc. (Morrison, 1992). Data limitations constrain the incorporation of such phenomena in our model.

Data and Variables Definition

The data used in this study were extracted from a survey undertaken by the Greek Institute of Agricultural Economics and Rural Sociology. Our analysis focuses on a sample of 110 olive growing farms; 60 farms are located in Peloponnisos, 30 in Crete, and 20 in Sterea Ellada. Observations were obtained on an annual basis for the period 1987-1993. The sample was selected with respect to production area, total number of farms within the area, number of olive trees on the farm, cultivated land area, and the share of olive oil production in farm output.

In terms of production costs the data set shows that labour constitutes the most dominant expense, followed by fixed assets interest, oil-mill payments, depreciation expenses, fertilizer and pesticides, with no great differences among regions. In spite of their small size and extensive fragmentation, olive growing farms enjoy high returns compared with other Greek farms. Particularly, farms in Peloponnisos had the highest net revenue per stremma ($30.3 and $35.9 in 1987 and 1993, respectively), followed by Cretan farms ($28.2 and $33.6). Corresponding values

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autonomous part is a function of time and the biased part depends on input quantities (Wylie, 1990).

for farms in Sterea Ellada were considerably lower ($21.2 and $27.8). Subsidies, however, represented more than 20 per cent of farms' total gross revenue in all three regions.

The dependent variable in the production frontier is annual olive oil production measured in kilograms. The aggregate inputs included as explanatory variables are: (a) total *labor*, comprised of hired, family and contract labor, measured in working hours; (b) *chemical fertilizers* measured in kilograms; (c) *other cost* expenses and capital inputs measured in Greek drachmas (constant 1990 prices); (d) *land* under olive tree cultivation measured in stremmas.

Empirical Results

Statistical testing indicated that both the pooled least squares and fixed effects models were rejected in favor of the random effects model for our current data set in all regions (Table 1). Further, the hypotheses of constant returns to scale and of zero and Hicks-neutral technical change were tested and rejected at the 10 per cent level of significance. Hence, technical change was found to be non-neutral and scale augmenting.

Table 1. Model Specification Tests

	Peloponnisos	**Crete**	**St. Ellada**	**Critical Value (α=0.01)**
Pooled LS vs GLS	14.1	13.5	12.0	$\chi^2_{(1)} = 6.63$
Pooled GLS vs LSDV	17.1	16.9	19.5	$\chi^2_{(10)} = 23.2$
Zero Technical Change	25.3	13.1	12.7	$\chi^2_{(6)} = 16.8$
Hicks-Neutral TC	19.5	9.4	7.9	$\chi^2_{(4)} = 13.3$
CRTS	38.4	30.7	25.9	$\chi^2_{(2)} = 9.2$

*The null hypothesis for constant returns to scale requires that $\sum \beta_j = 1 \wedge \sum \beta_{jt} = 0$, while the corresponding restrictions for zero and Hicks-neutral rate of technical change are $\beta_t = \beta_{tt} = \beta_{jt} = 0$ and $\beta_{jt} = 0$ $\forall$j, respectively.

Table 2 presents estimates of the rate of technical change and its decomposition into autonomous and biased components, evaluated at mean values of the data over farms and time. These estimates indicate significant technical progress in Peloponnisos and Sterea Ellada throughout the study period, while in Crete the corresponding point estimate is considerably lower. The pattern of overall technical change in Peloponnisos and Sterea Ellada is determined by the autonomous portion, however in Crete both the autonomous and biased portions contribute almost evenly to the overall value.

Table 2. Technical Change for Greek Olive-Growing Farms, 1987-1993

	Peloponnisos	*Crete*	*Sterea Ellada*
Total	4.62	0.90	3.95
Autonomous portion	3.81	0.43	3.31
Biased portion	0.81	0.47	0.64

Although no major breakthrough in crop production technology occurred during the 1987-93 period, it seems that the existing subsidies mechanism within the EU has acted as an incentive for farmers in Peloponnisos and Sterea Ellada to introduce technological innovations. The high average yield of olive oil along with the larger farm size in Crete might explain the relatively slower adoption of new technologies by Cretan farmers. Large farms with high profit margins under protective agricultural policy schemes do not easily embrace to new technologies. In general, high profitability decreases the pressure to utilize technological innovations (Kalaitzadonakes). Finally, there were significant differences in the biases of technical change among regions. Specifically, technological innovations in olive farming were using towards fertilizer in Peloponnisos, but using towards labour and other cost expenses in Crete and Sterea Ellada.

Average estimates of production elasticities and returns to scale over farms and time are presented in Table 3. These figures indicate that land has contributed the most to olive oil production, followed by labour, fertilizer and other expenses. These patterns remain unchanged across regions, although the absolute magnitude of these estimates differs considerably. Considering the existing acreage limitations and the high opportunity cost of land, land remains an important factor of production. Returns to scale were strongly diminishing in all three regions.

Table 3. Production Elasticities and Returns to Scale, 1987-1993

	Peloponnisos	*Crete*	*Sterea Ellada*
Labor	0.117	0.110	0.116
Fertilizer	0.023	0.020	0.033
Other Cost	0.006	0.002	0.030
Land	0.482	0.672	0.541
RTS	0.628	0.804	0.719

Economic Efficiency

Table 4 presents the estimated average technical, allocative, and economic efficiency measures over farms and time for each region. Olive growing farms are significantly both technical and allocative inefficient in all regions. The gap between average and best practice yield is significant for the sample participants and follows an increasing trend over time. The level of allocative efficiency was found to be lower than the level of technical efficiency, indicating that relatively more cost savings can be achieved by improving allocative rather than technical efficiency. However, the results imply that there are significant savings to be realized by improving both. The comparison across regions shows that Cretan farms have the highest average technical and allocative efficiency scores.

Table 4. Mean Technical, Allocative and Economic Efficiencies (1987-93)

Efficiency	*Peloponnisos*			*Crete*			*Sterea Ellada*		
%	TE	AE	EE	TE	AE	EE	TE	AE	EE
Mean	68.1	65.3	46.4	70.4	68.9	49.6	65.2	56.8	39.0
Min	49.4	46.2	24.6	56.8	59.3	38.2	49.3	43.4	22.1
Max	92.6	82.4	75.4	86.6	89.7	68.8	78.6	69.9	55.5

The small size and extensive fragmentation of Greek olive growing farms might be among the reasons for the low efficiency scores. Another explanation of the low levels of economic efficiency among farms might be the perennial nature of the olive tree. The latter reduces significantly producers' flexibility, including the ability to adjust to an uncertain economic environment caused by yield and price variability. Yield variability affects input choices and particularly those regarding capital inputs, which are less flexible than labour or land.

Finally, the extensive protectionism enjoyed by the sector after Greek accession into the EU might also assist in understanding the negative pattern of efficiency scores during the study period. Although CAP created an incentive for production growth and adoption of new technologies, it prevented producers from operating under *laissez-faire* conditions. The lack of external competition and entrepreneurial motives made farmers less responsive to market signals. Although protectionism may stimulate investment and new technology adoption, efficiency may decrease particularly when farm prices and thus, income are high (Tzouvelekas *et al*., 1997; Mundlak, 1988).

Explaining Production Growth

Table 5 presents the decomposition of output growth realized during 1987-1993. Over the entire period, olive oil production grew at an average annual rate of 6.87, 6.75 and 6.95 per cent in

Peloponnisos, Crete, and Sterea Ellada, respectively. This growth stems mainly from the increase in the use of inputs and, to a lesser extent, from total factor productivity growth. In particular, the increased use of conventional inputs accounted for 55 and 60 per cent of output growth in Crete and Sterea Ellada, while in Peloponnisos the relevant figure is 46.4 per cent.

Table 5. Decomposition of Output Growth for Greek Olive-Growing Farms

1987-1993	*Peloponnisos*	*Crete*	*Sterea Ellada*
Output Growth	6.87 *(100.0)*	6.75 *(100.0)*	6.95 *(100.0)*
Total Input Growth	3.19 *(46.4)*	3.72 *(55.1)*	4.17 *(60.0)*
Labor	1.22	1.49	1.55
Fertilizer	0.71	0.62	1.01
Other Cost	0.07	0.03	0.33
Land	1.19	1.58	1.28
TFP Growth	2.72 *(39.6)*	1.32 *(19.6)*	1.77 *(25.5)*
Technical Change	4.62 *(67.2)*	0.90 *(13.4)*	3.95 *(56.8)*
Autonomous	3.81	0.43	3.31
Biased	0.81	0.47	0.64
Scale Effect	-1.49 *(-21.6)*	-0.71 *(-10.5)*	-1.31 *(-18.8)*
TE Change	-0.64 *(-9.24)*	-0.12 *(-1.78)*	-0.29 *(-4.17)*
AE Change	-1.24 *(-17.9)*	-0.42 *(-6.15)*	-1.25 *(-17.9)*
Price Effect	1.47 *(21.4)*	1.67 *(24.7)*	0.68 *(9.57)*
Unexplained Residuals	0.96 *(13.9)*	1.71 *(25.4)*	1.01 *(14.5)*

*Numbers in parentheses represent percentage contributions to total output growth.

The increase in labour use explains a significant portion (almost 40 per cent) of total input growth, with no substantial differences between regions. The increase in land area also has a significant effect on that growth. However, land exhibits a decline over time mainly due to acreage limitations. Finally, increased fertilizer use accounts for almost 20 per cent of total input growth, while for other expenses the relevant share is considerably lower.

On the other hand, TFP accounted for only 19.6 per cent of olive oil production growth in Crete, 25.5 per cent in Sterea Ellada and 39.6 per cent in Peloponnisos. Technical change was found to be the main element of TFP growth, accounting for 67.2 per cent in Peloponnisos, 56.8 per cent in Sterea Ellada and 13.4 per cent in Crete. Technical and allocative inefficiencies were both significant, causing a productivity slowdown during the study period. Low levels of economic efficiency among olive-growing farms imply that the growth-promoting impacts of technological innovations may not constitute the overriding source for longer-run TFP improvements.

The bias in the use of inputs due to allocative inefficiencies (price effect) also contributes significantly to TFP and, thus, to output growth. In Peloponnisos and Crete the corresponding shares are significant (21.4 and 24.7 per cent, respectively), but in Sterea Ellada only 9.57 per cent. Finally, diseconomies of scale cause an annual slowdown in total production growth of around 21 per cent in Peloponnisos, 10.5 per cent in Crete, and 18.8 per cent in Sterea Ellada. Omission of the scale effect would result in overestimation of both TFP and output growth.

Although decomposition analysis framework has been extended in our analysis, a significant part of annual olive oil production growth remains unexplained for our data set. This unexplained portion of output growth contributed an average of 13.9 per cent to annual growth in Peloponnisos, 25.4 per cent in Crete and 14.5 per cent in Sterea Ellada. However, data limitations precluded the incorporation of subequilibrium effects into the current analysis.

Conclusions

The extent of economic efficiency among olive-growing farms in the most productive regions of Greece is analyzed. The impact of resource use and total factor productivity on output growth is also examined. Empirical results suggest that olive growing farms in the sample were significantly both technical and allocative inefficient in all three regions under consideration. The extensive protectionism of the olive oil market, along with the agrarian structure of the sector in Greece, and the peculiar nature of the olive tree itself resulted in a persistent level of inefficiency. At the same time, supply responses to price supports generated significant olive oil production growth.

Output growth decomposition analysis indicated the increased use of conventional inputs as the primary source of output growth. The contribution of total factor productivity to output growth was also important and stemmed mainly from the introduction and utilization of technological innovations during the study period. The results also show that costless output increases can be obtained by improving resource allocation and, therefore, productive efficiency.

In an era of fiscal austerity and limited or costly technological opportunities, incentives for investment in human capital would improve farmer's technical skills and managerial abilities. Both are necessary and sufficient conditions for increased adoption and full exploitation of technologies, TFP improvements, and output growth. When accompanied by significant demand increases, supply shifts can have positive effects on rural incomes and employment. The role of private and governmental institutions in assisting farmers to improve their managerial skills and hence their efficiency levels, is crucial.

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