Evaluating the Impact of Public and Private Agricultural Extension on Farms Performance: A Non-neutral Stochastic Frontier Approach

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1. Introduction

A composite role on output growth could been assigned to agricultural extension compared to R&D which affect productivity only through technical change (Alston and Pardey). In particular, agricultural extension not only accelerates the diffusion process and the adoption of new technologies but also affects the utilization of these technologies by improving farmers' know how. That is, apart from providing information about new farming techniques and high-yielding varieties, extension agents also assist farmers in the development of their managerial skills, facilitating a shift to more efficient production. in this sense it can narrow the gap between current and the potential productivity, given the existing set of technology and management alternatives. Thus, in in a continuously changing economic environment agricultural extension has the potential of enhancing the efficiency of farm operations and thus affecting the overall productivity.

The literature on the impact of agricultural extension on farm productivity has followed two different tracks. The early empirical studies (e.g., Patrick and Kehrberg; Huffman) hinged on the estimation of a production function, where extension had been considered as a separate factor of production (for a review of these studies see Birkhaeuser, Evenson and Feder). This production-based approach assumes that farms are operating at technically full efficient levels and thus do not knowingly waste resources. If, however, they waste resources but are ignorant of doing so, this is only due to lack of knowledge. Within this approach the impact of extension on farms performance is evaluated through its marginal product and in a sense captures its direct effect on output. On the other hand, in the context of stochastic frontier models, the analysis of agricultural extension took a different direction. As the assumption of technical efficiency was relaxed, extension was used as a factor explaining individual technical efficiency levels rather than as an input in the production function (e.g., Kalirajan; Kumbhakar, Ghosh and McGuckin; Bravo-Ureta and Evenson). Within this approach, the impact of extension on farm product is indirect as it is evaluated through the potential output gain due to elimination of technical inefficiency. Even though informative at that time, both approaches can be criticized as incomplete since it is intuitively more appealing to include extension both in the production function and in the inefficiency effects function.

The main objective of this paper is to integrate both approaches into a single framework using the notion of non-neutral stochastic production frontier proposed by Huang and Liu and Kalirajan and Obwona. The intuition behind the proposed formulation is that different levels and/or sources of extension (i.e., public, private, or both) may influence output differently causing a diversity in input productivities as well as in the marginal rates of technical substitution among firms. Consequently, the effects of technical inefficiency on input productivity may be greater on some inputs than on others implying that the estimated frontier would more accurately be modeled as a non-neutral shift of the traditional 'average' production function. Moreover, each of the aforementioned approach can be retrieved as a special case within the proposed formulation. That is, formal statistical testing is used to check whether extension should be included only in the production function or in the inefficiency effect function, or in both. In the latter case, an empirical evaluation of both the direct and indirect effects of agricultural extension can be obtained.

Unlike previous studies, a clear distinction is drawn between public (non-fee) and private (paid) sources of extension. This is essential considering the significant changes that took place worldwide in the last twenty years concerning the structure of extension systems and the involvement of public and private sectors in financing and providing extension services (Dancey; Dinar, 1989; 1996).[1] Discriminating among different farmers' choices enables the identification of potential benefits that may arise from different sources of extension provision for individual farm productivity (Dinar and Keynan). In that respect, it would be important from a policy point of view to obtain an empirical comparative evaluation of the individual effects (direct and indirect) that public and private extension services may have on farm productivity. Indeed we attempt to document the hypothesis of complementarity between public and private extension services. The analysis is based on a sample of

265 farms in Crete, Greece during the period 1995-96 and on a modified translog production frontier function to account for possible zero entries as some farms in the sample were not exposed at all to any kind of extension services.

The rest of the paper is organized as follows. Section 2 presents the theoretical framework and the empirical specification of the model. The data used in this study are discussed in Section 3 and the empirical results are analyzed in Section 4. Section 7 summarizes and concludes the paper.

2. Theoretical Framework

Let assume that the stochastic production frontier model has the following general form:

$$Y = f(X, EX; \alpha) exp(\varepsilon) \qquad (1)$$

where, $Y \in R_{++}$ is the ($Nx1$) vector of farm output, $X \in R_{+}$ is the (NxJ) matrix of the applied inputs in the production process, $EX \in R_{+}$ is the ($Nx2$) vector of extension visits (public and private) in the farm, $f(\bullet)$ is the best practice production frontier, α is the ($Jx1$) vector of the technology parameters, i=1, 2, …, n and j=1, 2, …, J denote farms and applied inputs, respectively, and ε is the ($Nx1$) vector of the composed error term consisting of two independent elements such that $\varepsilon \equiv v - u$. The component v is a symmetric *i.i.d.* error term that represents random variation in output due to factors not under farmers' control (weather, diseases, etc.) as well as the effects of omitted explanatory variables, measurement errors, and statistical noise. The component u is a non-negative error term representing the stochastic shortfall of farms' output from the production frontier due to technical inefficiency. Thus, technical inefficiency is defined in an output-expanding manner indicating the maximum amount by which output can be increased given the production technology and observed input usage.[2]

In the above general setup we can only measure the direct effect of extension on agricultural production through its inclusion in the production frontier together with physical inputs. The identification of the indirect effect requires knowledge of the impact of extension on individual technical inefficiency. This can be done by adopting Huang and Liu's generalization of the stochastic frontier model. In particular, u in (1) can be replaced by a linear function of extension and farm-specific characteristics that presumably affect individual farmers' performance. Specifically,

$$u = g(Z, EX; \zeta) + \omega \qquad (2)$$

where Z is the (NxM) matrix of the m=1, 2, …, M farm-specific characteristics (*i.e.*, age, education, size) that are assumed to affect technical inefficiency, ζ is the ($Mx1$) vector of the parameters to be estimated and, ω is an *i.i.d.* random term defined by the truncation of the normal distribution such that $\omega \geq -[g(Z, EX; \zeta)]$.[3] This implies that the one-sided error term follows a truncated half-normal distribution with mean $\mu = g(Z, EX; \zeta)$ and constant variance. Under this assumption farm-specific estimates of output-oriented technical efficiency can be derived from the conditional expectation of u upon the observed value of ε.

Given the above specification of the production frontier it is possible to evaluate both direct and indirect effects of agricultural extension on individual farms' output. That is, after substituting (2) into (1) and differentiating it with respect to the extension variable (public or private), we get:

$$\frac{\partial E(Y)}{\partial EX} = \frac{\partial f(X, EX; \alpha)}{\partial EX} - \frac{\partial E\{g(Z, EX; \zeta)\}}{\partial EX} \qquad (3)$$

where the first-term on the RHS is the *direct* effect of extension on farms output, *i.e.*, its impact on the productivity of conventional inputs, while the second-term is the *indirect* effect of agricultural extension, *i.e.*, its impact on the efficient utilization of the available resources. If farmers are technically efficient the indirect effect is zero and the impact of extension on farms' productivity is determined solely by the direct effect. However, the indirect effect could also be zero in the presence of technical inefficiency as long as the later is independent of extension services.

To provide quantitative estimates of the direct and indirect effects of (public and private) extension on farm output, (1) is modeled as a modified translog, i.e.,:

$$\begin{aligned} ln\, y_i = {} & \alpha_0 + \sum_{j=1}^{4} \alpha_j \, ln\, x_{ji} + \frac{1}{2}\sum_{j=1}^{4}\sum_{k=1}^{4} \alpha_{jk} \, ln\, x_{ji} \, ln\, x_{ki} + \beta_{Ar} AR_i + \beta_{At} AT_i \\ & + \sum_{d=1}^{3} \beta_d SD_{di} + \sum_{l=1}^{2} \delta_l EX_{li}^{(\lambda)} + \frac{1}{2}\sum_{l=1}^{2}\sum_{h=1}^{2} \delta_{lh} EX_{li}^{(\lambda)} EX_{hi}^{(\lambda)} \\ & + \frac{1}{2}\sum_{j=1}^{4}\sum_{l=1}^{2} \delta_{lj} \, ln\, x_{ji} EX_l^{(\lambda)} + v_i - u_i \end{aligned} \qquad (4a)$$

and

$$u_i = \zeta_0 + \sum_{m=1}^{9} \zeta_m z_{mi} + \sum_{l=1}^{2} \zeta_l EX_{li}^{(\lambda)} + \zeta_{lh} EX_{li}^{(\lambda)} EX_{hi}^{(\lambda)} + \sum_{m=1}^{9}\sum_{l=1}^{2} \zeta_{ml} z_{mi} EX_{li}^{(\lambda)} + \omega_i \quad (4b)$$

where, i=1, 2, ..., 265 are the number of farms in the sample, j,k=1, 2, ..., 4 are the physical inputs applied in farm production, *AR* refers to an aridity index, *AT* to an altitude index, *SD* to soil dummies, l=1, 2 are the public (non-fee) and private (paid) extension contacts, and m=1, 2, …, 9 are the farm-specific variables assumed to affect farmers' technical inefficiency levels. In order to deal with zero values and at the same time obtain unbiased estimates of the frontier function parameters, public and private extension visits are transformed using the Box-Cox transformation function, i.e., : $EX_i^{(\lambda)} = (EX_i^{\lambda} - 1)/\lambda$.

After substituting (*4b*) into (*4a*) the resulting model can be estimated by a single-equation estimation procedure using the maximum likelihood technique. Following Battese and Broca, the variance parameters of the likelihood function can be estimated in terms of $\sigma^2 \equiv \sigma_v^2 + \sigma_u^2$ and $\gamma \equiv \sigma_u^2 / \sigma^2$.[4] The ratio-parameter γ takes values between zero and one. The closer the estimated value of γ to one, the higher the probability that technical inefficiency is significant in explaining output variability among sample participants. Given however the transformation of the extension variables and the resulting non-linearities, the final estimation was carried out as in Giannakas, Tran and Tzouvelekas by using a bi-dimensional grid search around the 0-2 range for the value of λ.

The production-based and the inefficiency effect approaches on modeling the impact of extension on farm output can be retrieved as special cases of the general formulation (1) and (2) by imposing the appropriate parametric restrictions on (4a) and (4b). In particular, a strict version of the former results if $\gamma = \vartheta_0 = \vartheta_m = \vartheta_l = \vartheta_{ih} = \vartheta_{ml} = 0$ for all *m*, *l*, and *h*, which imply that the systematic technical inefficiency effects are zero and consequently, each farm in the sample operates on the frontier.[5] These restrictions arise from Welch argument that since extension is considered as the only source of knowledge for farmers, its inclusion in the average production function makes the concept of technical efficiency something of a tautology. A less restrictive version of the production-based formulation may be obtained by assuming that $\vartheta_l = \vartheta_{ih} = \vartheta_{ml} = 0$ for all *m*, *l*, and *h*, which allows for technical inefficiency but independently of extension. On the other hand, the inefficiency effect approach results if $\delta_l = \delta_{lh} = \delta_{lj} = 0$ for all *l*, *h* and *j*. Apparently, all previous studies used a quite simpler formulation where also $\vartheta_{ih} = \vartheta_{ml} = 0$ for all for all *m*, *l*, and *h*.

Using (3) and (4a), the direct effects of public or private extension on production coincide with their output elasticities.[6] That is,

$$e_{li} = \delta_l EX_{li}^{\lambda} + 0.5\sum_{h=1}^{2} \delta_{lh} EX_{li}^{\lambda} EX_{hi}^{(\lambda)} + 0.5\sum_{j=1}^{4} \delta_{lj} EX_{li}^{\lambda} \ln x_{ji} \qquad (5)$$

which also depends on conventional inputs usage. The second-term on the RHS of (8) provides the potential interaction effect between public and private extension on farm productivity.[7] On the other hand, the indirect effect of public or private extension on farms' output through its impact on individual technical inefficiency levels is obtained by using (3) and (4b) as:

$$\frac{\partial \ln E(-u_i|\varepsilon_i)}{\partial lnEX_i} = -\xi\left(\zeta_l EX_{li}^{\lambda} + \zeta_{lh} EX_{li}^{\lambda} EX_{hi}^{(\lambda)} + \sum_{m=1}^{9} \zeta_{lm} EX_{li}^{\lambda} z_{mi} \right) \qquad (6)$$

where $\xi = 1 - \sigma_u^{-1}\left\{ \frac{\phi(\rho - \sigma_u)}{\Phi(\rho - \sigma_u)} - \frac{\phi(\rho)}{\Phi(\rho)} \right\}$, $\rho = \mu_i / \sigma_u$ and $\phi(\bullet)$ and $\Phi(\bullet)$ are the probability and the cumulative density functions of the standard normal variable.

Farm-specific estimates of output-oriented technical inefficiency are obtained directly from the estimated mean and variance of u_I as follows (Battese and Broca):

$$TE_i^O = E\{exp(-u_i)|\varepsilon_i\} = exp\left(-\mu_i^0 + 0.5\sigma_o^2\right)\left\{ \frac{\Phi\left[\left(\mu_i^0/\sigma_o\right) - \sigma_o\right]}{\Phi\left(\mu_i^0/\sigma_o\right)} \right\} \qquad (7)$$

where $\mu_i^0 = \frac{\sigma_v^2 \mu_i - \sigma_u^2 \varepsilon_i}{\sigma_v^2 + \sigma_u^2}$, $\sigma_o^2 = \frac{\sigma_u^2 \sigma_v^2}{\sigma_u^2 + \sigma_v^2}$ and *E* is the expectation operator. One can easily calculate from the above the corresponding variance and thus the standard errors of $E\{exp(-u_i)|\varepsilon_i\}$ by linearizing (7) (Tsionas). Using these standard errors we can statistically examine by simple two-tail test whether there are differences in the predicted technical inefficiency between farms with different choice of extension provision (Mester).

5. Data Description

Data used in this study are part of a broader survey on the structural characteristics of the agricultural sector in Crete financed by the Regional Directorate of Crete in the context of the *Regional Development Program 1995-99* (Liodakis). The sample consists of 265 randomly selected farms located in the four major districts of Crete, namely Chania, Rethymno, Heraklio and Lasithi, during the 1995-96 period. The survey provides detailed information about production patterns, input use, average yields, gross revenues, structural characteristics and the number of visits of both private and public extension agents to the farm. Descriptive statistics are provided in Tables 1 and 2.[8]

During the year of the survey, extension services in Crete were provided by 18 public (non-fee) and 72 private (paid) agencies. Public extension outlets consist of the 10 Regional Offices of the Agricultural Extension Directorate and 8 Agricultural Experimental Stations located in the major rural areas of the island (Table 1). Private outlets are of smaller capacity, exhibiting however, a wider dispersion around Crete. This is evident from their average distance from the surveyed farms presented in the middle panel of Table 1. Specifically, average distance of public outlets from the surveyed farms is 39 km, whereas the corresponding value of private outlets is nearly four time lower, 10 km.

Public outlets employ 267 persons, while in private outlets the corresponding figure is 314 persons. However, on the average extension agents per private outlet are 4 persons, considerably lower than the corresponding value for public outlets which is 14 persons. Private extension agents are more educated than their public counterparts as average education levels are 13.4 and 11.5 years, respectively. However, the majority of public agents are very close to the retirement age (the average experience of public extension agents is 28.9 years, while that of private extension agents is only 14.2 years). Finally, average office hours per day available for farmers are 6.8 and 5.4 hrs/day, respectively in private and public outlets. This is due to the fact that private agencies are usually open in the afternoon.

Concerning farmers' choice the data presented in the middle panel of Table 1 reveal that 37.7 percent of the surveyed farms (100 farms) prefer exclusively public agencies, 17.4 percent (46 farms) private agencies, 33.2 percent (88 farms) both public and private agencies, while the remaining 11.7 percent (31 farms) do not report any extension visit during the year of the survey.

Concerning farmers' perceptions of the quality of the provided services, 46.8 percent of the farms visited by public extension agents perceive them as very good, 37.8 percent as good, and the remaining 15.4 percent as poor (lower panel of Table 1). At the same time, only 4.5 percent of the farms visited by private extension agents regard the provided services as poor, 41.0 percent as good and the other 54.5 percent, as very good. It seems therefore that despite the fact that the majority of Cretan farmers prefer public extension for obtaining technical information, they rate the provided services as less satisfactory than those provided by private extension agents.

Table 2 presents some basic socio-economic and structural characteristics of the surveyed farms by extension source. From the data presented, it is evident that large intensive farms more specialized in their production and with higher debts are visited mainly by private extension agents. It is interesting that average production value is 406 €/stremma for farms visited by private extension agents, 322 €/stremma for those visited by both public and private extension agents, 285 €/stremma for those visited by public extension agents and only 244 €/stremma for those that do not use extension at all.

Furthermore, older farmers who are in general less educated than their younger counterparts are visited mainly by public extension agents. The average age and education level of farmers using public extension is 56 and 7.8 years, respectively, whereas for farmers using private extension the corresponding values are 45 and 9.2 years. The possible correlation between public extension and the level of subsidies can be explained by the fact that public extension agents are responsible for the implementation of the various CMOs in the context of CAP.

Finally, farms enjoying more favorable environmental conditions seems to prefer private extension. Farms visited by private extension agents are mainly located in sandy and limestone soils, which are generally more productive, with higher average annual temperature.

The dependent variable in (*4a*) is the annual farm production measured in euros. The aggregate inputs included as explanatory variables are: (*a*) farms' total land measured in stremmas (1 stremma equals 0.1 ha); (*b*) total labor, comprising hired and family (paid and unpaid) labor, which includes all farm activities related to farm production, measured in hours; (*c*) other intermediate inputs, consisting of pesticides, fertilizers, fuel and electric power, irrigation taxes, and other miscellaneous expenses, measured in euros, and; (*d*) total capital inputs including machinery and equipment, measured in euros; (*e*) an aridity index (AR_i) defined as the ratio of the average annual temperature in the region over the total annual precipitation (Stallings); (*f*) the altitude of farms' location (AT_i) in meters; (*g*) three soil-dummies (SD_{di} with d=1, 2, 3) to distinguish soil quality among farms (sandy, limestone, marls); (*h*) public and private extension services $\left(EX_{li}^{(\lambda)}\right)$ measured as the number of visits to the farm.

Aggregation over the various components of the above output and input categories (except for land input) was conducted using *Divisia* indices with revenue and cost shares serving as weights. Furthermore, to avoid any problems associated with units of measurement, all (but the dummy) variables were converted into indices with the basis of normalization being the representative farm. The choice of the representative farm was based on the smallest deviation of the variables (*i.e.*, output and input levels) from the sample means.

Concerning the variables included in the inefficiency effects model in (*4b*) these include: (*a*) farmers' age measured in years; (*b*) farmers' formal education measured in years of schooling; (*c*) farms' tenancy status measured as the share of leased or rented land to total farm's land; (*d*) farms' debts measured in euros; (*e*) total amount of subsidies received by farmers in the context of the CAP measured in euros; (*f*) the total off-farm income arising from non-farm activities of the household, measured in euros; (*g*) the share of self-consumption of total farm produce; (*h*) the degree of farms' specialization measured as a *Herfindhal* index;[9] (*g*) a dummy variable indicating intensive farming operations.

The modified translog stochastic frontier and inefficiency effects models in (4a) and (4b) were jointly estimated using the maximum likelihood methodSince the employed data set was generated by an unknown technology, the regularity conditions, apart from symmetry, were assumed rather than imposed.

6. Empirical Results

ML Estimates

The parameter estimates of the production frontier and inefficiency effects model along with their corresponding standard errors are reported in Table 3. The Box-Cox transformation parameter, λ, that minimizes the logarithm of the likelihood function, was found to be 0.9871 which is statistically significant at the 1 percent level. At the point of approximation (*i.e.*, sample mean), the modified translog production frontier is well-behaved satisfying all regularity conditions, namely positive and diminishing marginal products (the first-order parameters are all between zero and one, while the bordered Hessian matrix of the first- and second-order partial derivatives is negative semi-definite).

The variance parameters, σ^2 and γ, are shown in the lower part of Table 3. The true variance for the one-sided error term, σ_u^{2*}, computed from these estimates, was found to be 0.333 and that of the statistical noise, σ_v^{2*}, 0.046 (see footnote 9). The ratio-parameter, γ, is positive and statistically significant at the 1 percent level, indicating that the technical inefficiency is likely to have an important effect in explaining output variability among Cretan farms.

Specifically, the computed variance-ratio, γ^*, (see footnote 9) implies that 67.8 percent of the total variability of output produced is due to technical inefficiency, whereas the remaining portion (*i.e.*, 1- γ^*=0.322) is due to measurement errors, specification biases and factors that are not incorporated in the stochastic frontier and inefficiency effects models.

Several hypotheses concerning the specification of the production frontier model in (4a) and (4b) are examined using the likelihood ratio test and the results are presented in Table 4. First, restrictive functional forms such as the Cobb-Douglas specification is rejected at the 5 percent level of significance using likelihood ratio test (1st hypothesis in Table 4). In addition, the hypothesis that the average response function (*i.e.*, u_i=0) adequately represents the data set is rejected regardless of whether inefficiency effects are present[10] (2nd hypothesis in Table 4) or absent (3rd hypothesis in Table 4) in the production function model. Thus, the existing degree of technical inefficiency is an important factor in explaining output variability among farms in the sample.

Moreover, the stochastic frontier model cannot be reduced either to the Aigner, Lovell and Schmidt half-normal or to the Stevenson truncated half-normal specification as the respective null hypotheses are rejected at the 5 percent level of significance (4th and 5th hypotheses in Table 4, respectively). Finally, the hypothesis that the estimated coefficients of the variables included in the inefficiency effects model in (4b) are jointly equal to zero is also rejected at the 5 percent level (6th hypothesis).

Hence, agricultural extension (public or private) together with the socio-economic and structural characteristics of Cretan farms are likely to have an important role in determining the economic performance of Cretan farms. An important question that arises, however, is the nature of the effect of agricultural extension and its distinction between public and private sources. Statistical testing also presented in Table 4 examines this issue.

First, the hypothesis that all the parameters associated with agricultural extension (public and private) in both the production frontier and inefficiency effects model are jointly equal to zero is rejected at the 5 percent level of significance (7^{th} hypothesis in Table 4). The LR-test statistic also rejects the hypotheses that agricultural extension (public or private) affects either directly (8^{th} hypothesis) or indirectly (9^{th} hypothesis) economic performance of farms.

The same conclusion can be drawn if the effect of agricultural extension is discriminated between public and private sources. Specifically, the joint direct and indirect effect of either public or private agricultural extension services on farm productivity is important and statistically significant at the 5 percent level (10^{th} and 11^{th} hypotheses in Table 4, respectively).

This is also true when direct and indirect effects are examined separately (hypotheses 12 through 15). Concerning the nature of these effects the relevant hypotheses testing presented in Table 5 suggests that these are non-neutral regardless of the source of extension (hypotheses 16 through 21). Finally, it seems that there exists an important and statistically significant interaction between public and private extension services concerning both their direct and indirect effect on farms productivity as the hypotheses 22 through 24 in Table 4 are rejected at a significance level of 5 percent.

Thus, statistical testing empirically validates the assumption made at the outset concerning the impact of agricultural extension on farms productivity levels. The results suggest that public and private extension services affect both directly and indirectly the productivity of Cretan farms through their effect on the marginal productivities of physical inputs as well as on the attained technical inefficiency levels.

Production Structure and Agricultural Extension

Based on the modified translog parameter estimates, reported in Table 3, we computed basic features of the production structure, namely output elasticities and returns to scale. Average values of these estimates over farms are presented in Table 5 by extension source.

First, Cretan farms in the sample exhibit, on average, decreasing returns to scale regardless of their choice of extension services. This finding is consistent with statistical testing that rejects the constant returns to scale translog (*i.e.*, linearly homogeneous production technology) at any conventional level of significance (see last hypothesis in Table 4). The small size of Cretan farms (5.1 ha on average) is probably responsible for the existence of diminishing returns. The lowest RTS value is observed for farms that are not visited at all by extension agents (0.7510) and the highest for those farmers visited only by private extension agents (0.8431).

Estimates of production elasticities of physical inputs using Eq. (7) indicate that land has contributed the most to Cretan farm production, followed by labor, intermediate inputs and capital. Their magnitude nonetheless varies with extension source. Farms visited exclusively by private extension agents exhibit the highest land and labour elasticity value (0.3527 and 0.1814, respectively) and the lowest elasticity with respect to capital (0.0892). On the other hand, farms with no extension exhibit the highest elasticity value with respect to capital (0.1777) and intermediate inputs (0.1321) but the lowest land elasticity (0.3017).

Favourable environmental and physical conditions positively affect farm production. The parameter estimate of the aridity index is negative and statistically significant at the 1 percent level, while two out of the three soil dummies (S2 and S3) associated with better soil quality (limestones and marls) are positive and statistically significant also at the 1 percent level. Finally, the altitude of farms location does not seem to have any impact on farm production as the relevant parameter estimate is not statistically significant at any conventional level.

The elasticity estimates with respect to public or private extension services computed using Eq. (8), are also reported in Table 5. These estimates represent the direct effect of public and private agricultural extension services on farm productivity. The highest elasticity value is observed for farms visited exclusively by private extension agents (0.1023) and the lowest for farms visited by public extension agents (0.0409). These values mean that a 1 percent increase in visits by public (private) extension agents would result *ceteris paribus* in a 0.1023 percent (0.0409 percent) increase in marketable output of Cretan farms. Using the mean values reported in Table 2, this means a 17.5€ and 6.5€ increase in farm production per visit, respectively.

It is quite interesting that the impact of public extension services on farm production, as measured by the corresponding elasticity value, is higher for farms visited by both private and public extension agents (0.0554) compared with farms visited only by public extension. Nonetheless, private agricultural extension services seem to have a larger direct effect on farm production compared with public extension services.

Technical Efficiency and Extension Source

The predicted farm-specific output-oriented technical efficiency measures for Cretan farms using Eq. (5) are presented in Table 6 in the form of a frequency distribution within a decile range. On average, the results reveal that Cretan farmers have not been successful in employing best-practice production technology and achieving the maximum possible output out of farming. Specifically, mean output-oriented technical efficiency over farms is 67.5 percent and statistically significant at the 1 percent level, indicating that a 32.5 percent increase in production is feasible with the current state of technology and unchanged input use (last column of Table 6).

Mean technical efficiency varies significantly among farms as it ranges from a minimum of 33.5 percent to a maximum of 99.9 percent. It is important that the majority of the Cretan farms in the sample are faced with severe technical inefficiency problems as only 21.1 percent of them achieved technical efficiency levels above 80 percent. Minimal width intervals of these technical efficiency estimates, computed using Eq. (6), are also found to vary considerably.[11] On average the difference between the lower and upper efficiency interval is 8.2 percent.

The results also show a difference between the attained levels of output-oriented technical efficiency and farmers' choice of the source of extension provision. The results presented in Table 6 suggest that farms' taking advantage of both kind of extension services (public and private) exhibit higher average technical efficiency levels, whereas farms with no extension services have the lowest mean value of technical efficiency.

Specifically, mean output-oriented technical efficiency for farms visited by both private and public extension agents is 76.6 percent, for farms visited only by private extension agents it is 72.5 percent, for farms visited only by public extension agents 66.7 percent and for farms that are not using agricultural extension only 54.2 percent. These mean values of the predicted technical efficiencies are all statistically different from zero.

The minimum value in Table 6 is observed for farms with no extension services (33.5 percent) and for farms visited only by public agents (38.5 percent), whereas the highest efficiency scores are observed for farms enjoying both kinds of extension (99.9 percent) and for farms visited only by public agents (99.8 percent). The corresponding computed minimum width intervals reveal that farms with no extension have the lowest range of the predicted mean technical efficiency (6.7 percent), while farms visited by private agents the highest (9.2 percent).

The conventional *t*-test presented in Table 7 confirms the existence of differences in the economic performance according to farmers' choice of extension provision source. Specifically, the *t*-test suggests that mean technical efficiency values between the four sub-samples are statistically significantly different from one another at the 5 percent or better level, except for the case between farms visited by private agents and farms visited by both private and public agents where the corresponding *t*-value is statistically significant at the 10 percent level.

The estimated 95 percent confidence intervals of the difference between the mean values of the predicted output-oriented technical efficiency are also presented in Table 7. These estimates reveal also that there are important differences between mean output-oriented technical efficiency for farms enjoying any kind of extension and farms that are not taking advantage of extension services (last three rows of Table 7). In accordance with statistical testing, the lowest confidence intervals of the differences between the mean values are observed for farms visited by both private and public extension agents and for farms visited solely by private extension agents. For the remaining two pair-cases the differences range between nearly 2 and 13.9 percent.

Thus, there is significant variation in output-oriented technical inefficiency between farms with different choices concerning the source of extension services. This is an important finding that should be taken into account in the process of reform of the extension provision system in Greece.

The indirect effect of agricultural extension (private and public) on farms' productivity *i.e.*, technical inefficiency levels, estimated using Eq. (9) and presented in Table 8, can also provide some valuable insights for important policy implications. The highest indirect effects are observed for farms enjoying both kinds of extension. Specifically, the indirect effect of public extension services is 0.0071 and that of private extension 0.0087 with both values being statistically significant at the 5 percent level. On the other hand, the lowest indirect effect is for farms enjoying public extension service (0.0059), whereas for farms visited only by private extension agents the corresponding value is somewhat higher (0.0065).

Regarding the decomposition of these effects, the results suggest that land tenancy (measured as the share of rented or leased land) and the off-farm income do not affect the indirect effect of all kinds of extension as the corresponding estimates resulted in statistically non-significant values. Subsidies seems to positively affect the indirect effect of only public extension services. Since the Regional Agricultural Extension Directorates have undertaken much of the administrative burden concerning the implementation of the CAP the result was rather expected.

Formal education positively affects the indirect effect of agricultural extension. This is uniform across farmers' choice although for private extension it is more in evidence. On the other hand, farmers' age being a proxy of his experience affect positively the indirect effect of only public extension provision. Hence, it seems that young, more educated farmers prefer private extension services, whereas their older counterparts prefer public extension services.

As the level of debts increases it seems that farmers switch to private extension agents to obtain the necessary technical information while the specialization and the intensity of farming operations positively affect the indirect effect of agricultural extension. Farms with a high share of self-consumption, which are usually of small capacity, do not use extension services. Finally, one striking thing to note is that in contrast to the direct effect, public extension positively affects the indirect effect of private extension and *vice versa*. The interaction effects reported in the last two columns of Table 8 are both positive and statistically significant at the 1 percent level.

Finally, the impact of the structural and socio-economic characteristics of the surveyed farms on their technical inefficiency levels, computed using Eq. (10), are shown in Table 9. First, farmers' age and formal education are both important factors affecting technical inefficiency levels. Education strongly complements most of the inputs utilized in the production process, such as chemical fertilizers, pesticides, irrigation and high-yielding varieties. Its importance is indispensable: schooling enhances both the information acquisition process and the efficiency in the use of the acquired information. This is also evident from the decomposition of the indirect effect of extension presented in Table 8 using Eq. (9).

Nevertheless, formal education may not be as important in performing an efficient function as hands-on *experience*. Thus, education as a proxy of human capital may become less important the longer a farmer is involved in the same farming activity; experience obtained through years and learning-by-doing have been argued to be critical in determining individual performance level. However, as noted by Weersink, Turvey and Godah, inexperienced (younger) farmers may tend to acquire knowledge about recent technological advances more easily than their older counterparts. This reason is probably behind the negative and statistically significant elasticity effect for farms using only private extension services (characterized by younger farmers).

Farms' debts positively affect individual technical efficiency levels only for farms using exclusively private extension services, whereas subsidies are significant only for farms using public or both kinds of extension services. Farms without many off-farm activities (increased specialization) exhibit higher technical efficiency values, whereas the intensity of farming operations positively affects only farms using any kind of extension services. Finally, the high share of self-consumption is associated with low efficiency scores, whereas off-farm income and land tenancy do not affect individual technical efficiency (except for farms not using extension at all).

7. Conclusions and Policy Implications

This paper takes a fresh look at the way extension affects farmers' performance. Using a detailed data set from Cretan agriculture, a non-neutral stochastic production frontier model is developed. Specifically, extension impacts are measured both via their direct and indirect effect on farms' productivity. Having separate observations for several types of extension choices (public, private, public and private, and non extension), allows us to derive conclusions regarding the (direct and indirect) impact of each extension type on Cretan agriculture.

The results in this paper, in agreement with many findings of previous work, shed light on the interaction between extension, socio-economic and physical characteristics of farms. Some of the most important results in this paper, that also have policy implications for other countries, are discussed below.

First, public and private extension are complementary, and not necessarily exclusive of each other. As could be seen in this paper, farms that had access to both extension outlets, demonstrated a higher level of performance compared to all other single extension outlets, and of course to the case of no extension *ceteris paribus*. As can be seen from the results, average number of annual visits on farm is highest for Private and Public, followed by Private and concluded by Public.

What makes the combination of private and public extension that powerful? Our study measures extension by only one variable, the number of visits of the extension agent to the farm. We have no information on the nature of extension services provided by private and by public outlets. In the case of Crete, it is the nature of the issues addressed by public and private agents, that together cover the entire spectrum of needs of farms. This issue is of great importance for policy makers, and deserves further investigation.

Second, there is a kind of specialization in using private and public extension outlets. The findings of the study suggest that likely impacts are to be realized in certain farm types (e.g., capital intensive, specialization level, etc). In addition to being an interesting empirical finding, there are also several implications that could be of interest to policy makers. The recent wave of privatization of extension services in developing countries exhibits mixed results (see Dinar, 1996). Dinar and Keynan also indicate the selection of adequate farmers to participate in private extension projects in Nicaragua, and the fact that an inappropriate selection procedure caused farmers to discontinue their participation. Therefore, the nature of the private extension services should be matched to the type of farms they are engaged with.

Third, an important finding in the Cretan case is that farms with a high share of self-consumption, which are usually of small capacity, do not use extension services. An analogue to developing world, would suggest that subsistence farms do not demand extension services of any type. It would be interesting to check this finding against other studies in the developing world. However, information is scarce. Most data on private extension that exist, include paid extension that is still at a project level, thus being funded or partially funded by external donors. Once the project terminates, the test would be the sustainability of the system that was established.

References

Aigner, D.J., C.A.K. Lovell and P. Schmidt. Formulation and Estimation of Stochastic Frontier Production Function Models. *J. Econometrics*, 1977, 6: 21-37.

Battese, G.E. and S.S. Broca. Functional Forms of Stochastic Frontier Production Functions and Models for Technical Inefficiency Effects: A Comparative Study for Wheat Farmers in Pakistan. *J. Prod. Anal.*, 1997, 8: 395-414.

Battese, G.E. and T.J. Coelli. A Stochastic Frontier Production Function Incorporating a Model for Technical Inefficiency Effects. *Working Paper in Econometrics and Applied Statistics No 69*, Department of Econometrics, University of New England, Armidale, Australia, 1993.

Birkhaeuser, D., R.E. Evenson and G. Feder. The Economic Impact of Agricultural Extension. *Econ. Dev. Cult. Change*, 1991, 39: 610-650.

Bravo-Ureta, B.E. and R.E. Evenson. Efficiency in Agricultural Production: The Case of Peasant Farmers in Eastern Paraguay. *Agr. Econ.*, 1994, 10: 27-37.

Dancey, R.J. The Evolution of Agricultural Extension in England and Wales, Presidential Address. *J. Agr. Econ.*, 1993, 44: 375-393.

Dinar, A. Provision of and Request for Agricultural Extension Services. *Amer. J. Agr. Econ.*, 1989, 71: 375-393.

Dinar, A. Extension Commercialization: How Much to Charge for Extension Services. *Amer. J. Agr. Econ.*, 1996, 78: 1-12.

Dinar, A. and G. Keynan. Economics of Paid Extension: Lessons from Experience in Nicaragua. *Amer. J. Agr. Econ.*, 2001, 83: 769-776.

Evenson, R.E. Estimated Economic Consequences of PIDAP I and PIDAP II Programs for Crop Production. Yale University Economic Center, 1988.

Feder, G., R. Slade and L. Lau. The Impact of Agricultural Extension: The Training and Visiting System in Haryana. *World Bank Staff Working Paper* no 76, World Bank, Washington DC, 1985.

Førsund, F.R. On the Calculation of the Scale Elasticity in DEA Models. *J. Prod. Anal.*, 1996, 7: 283-302.

Giannakas, K., K. Tran and V. Tzouvelekas. Efficiency, Technological Change and Output Growth in Greek Olive-Growing Farms: A Box-Cox Approach. *App. Econ.*, 2000, 32: 909-917.

Giannakas, K., K. Tran and V. Tzouvelekas. On the Choice of Functional Form in Stochastic Frontier Modeling. *Emp. Econ.*, 2002 (forthcoming).

Greene, W.H. *Econometric Analysis*. New York: Prentice Hall Inc, 1993.

Greene, W.H. Frontier production functions in *Handbook of applied econometrics, Volume II: Microeconomics*, M.H. Pesaran and P. Schmidt (eds), Oxford: Blackwell Publishers, 1999.

Griliches, Z. Research Expenditures, Education, and the Aggregate Agricultural Production Function. *Amer. Econ. Rev.*, 1964, 54: 961-974.

Hjalmarsson, L., S.C. Kumbhakar and A. Heshmati. DEA, DFA and SFA: A Comparison. *J. Prod. Anal.*, 1996, 7: 303-327.

Horrace, W.C. and P. Schmidt. Confidence Statements for Efficiency Estimates from Stochastic Frontier Models. *J. Prod. Anal.*, 1996, 7: 303-327.

Huang, C.J. and J.T. Liu. Estimation of a Non-Neutral Stochastic Frontier Production Function. *J. Prod. Anal.*, 1994, 5: 171-180.

Huffman, W.E. Decision Making: The Role of Education. *Amer. J. Agr. Econ.*, 1974, 56: 85-97.

Huffman, W.E. Allocative Efficiency: The Role of Human Capital. *Quart. J. Econ.*, 1977, 91: 59-79.

Huffman, W.E. Black-White Human Capital Differences: Impact on Agricultural Productivity in the US South. *Amer. Econ. Rev.*, 1981, 71: 94-107.

Jamison, D. and L. Lau. *Farmer Education and Farm Efficiency*. World Bank Research Publications, Baltimore: John Hopkins Univ. Press, 1982.

Jamison, D. and P.R. Moock. Farmer Education and Farm Efficiency in Nepal: The Role of Schooling, Extension Services and Cognitive Skills. *World Dev.*, 1984, 12: 67-86.

Jondrow, J., C.A.K. Lovell, I.S. Materov and P. Schmidt. On the Estimation of Technical Inefficiency in the Stochastic Frontier Production Function Model. *J. Econometrics*, 1982, 19: 233-238.

Kalirajan, K.P. An Econometric Analysis of Yield Variability in Paddy Production. *Can. J. Agr. Econ.*, 1981, 29: 283-294.

Kidd A.D., J.P.A. Lamers, P.P. Ficarelli and V. Hoffmann. Privatising Agricultural Extension: *Caveat Emptor*. *J. Rural St.*, 2000, 95: 95-102.

Kodde, D.A. and F.C. Palm. Wald Criteria for Jointly Testing Equality and Inequality Restrictions. *Econometrica*, 1986, 54: 1243-48.

Koutsouris, A. Organisation of Extension Services in Greece in *Options Mediterranneenes, Serie A: Seminaires Mediterraneenes*, n. 38. Eds: R. Rubino and P. Morand-Fehr, FAO-CIHEAM-IMZ, 1999: 47-50.

Kumbhakar, S.C., S. Ghosh and J.T. McGuckin. A Generalized Production Frontier Approach for Estimating Determinants of Inefficiency in U.S. Dairy Farms. *J. Bus. Econ. Stat.*, 1991, 9: 279-86.

Liodakis, G. The Cretan Agricultural Sector: Structural Problems and Future Prospects. Chania: TUC Press, 2000 (in Greek).

Llewelyn R.V. and J.R. Williams. Nonparametric Analysis of Technical, Pure Technical and Scale Efficiencies for Food Crop Production in East Java, Indonesia. *Agr. Econ.*, 1996, 15: 113-126.

Meeusen, W. and J. Van der Broeck. Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error. *Int. Econ. Rev.*, 1977, 18: 435-44.

Mester, L.J. Measuring Efficiency at US Banks: Accounting for Heterogeneity is Important. *Eur. J. Oper. Research*, 1997, 98: 230-242.

Moock, P.R. Education and Technical Efficiency in Small-Farm Production. *Econ. Dev. Cult. Change*, 1980, 29: 723-739.

National Statistical Service of Greece. Census of Employment. Athens: NSSG, 1996.

Patrick, G.F. and E.W. Kehrberg. Costs and Returns of Education in Five Agricultural Areas of Eastern Brazil. *Amer. J. Agr. Econ.*, 1973, 55: 145-154.

Perraton, H.D., D. Jamison and F. Orivel. Mass Media for Agricultural Extension in Malawi, in *Basic Education and Agricultural Extension, Costs, Effects and Alternatives*, H.D. Perraton *et al.*, (eds) World Bank Staff Working Paper no 64, World Bank, Washington DC, 1983.

Pudasaini, S.P. The Effects of Education in Agriculture: Evidence from Nepal. *Amer. J. Agr. Econ.*, 1983, 65: 509-515.

Schulz, T.W. The Value of Ability to Deal with Disequilibria. *J. Econ. Liter.*, 1975, 13: 827-896.

Stallings, J.L. Weather Indexes. *J. Farm Econ.*, 1960, 42: 180-186.

Stevenson, R.E. Likelihood Functions for Generalized Stochastic Frontier Estimation. *J. Econometrics*, 1980, 13: 58-66.

Tsionas, E.G. Alternative Models for Inefficiency Effects in Stochastic Frontier Models. Working Paper, Athens University of Economics, 2001.

Weersink, A., C.G. Turvey and A. Godah. Decomposition Measures of Technical Efficiency for Ontario Dairy Farms. *Can. J. Agr. Econ.*, 1990, 38: 439-456.

Welch, F. Education in Production. *J. Polit. Econ.*, 1970, 78: 35-59.

Table 1

An Overview of Agricultural Extension Provision in Crete, Greece

		Mean	Max	Min	Stdev
Public Extension:					
Outlets	18				
Agents	267				
Agents per Outlet		14	23	5	6.1
Office hrs per day		5.4	10	6	2.3
Staff Experience (years)		28.9	34	21	4.9
Staff Education (years)		11.5	20	9	5.3
Private Extension:					
Outlets	72				
Agents	314				
Agents per Outlet		4	7	2	1.8
Office hrs per day		6.8	12	5	3.1
Staff Experience (years)		14.2	22	3	6.3
Staff Education (years)		13.4	20	9	4.1
Farmers' Choice	No of Farms[1]				
Public Extension	100 (37.7)				
No of visits		5	13	1	5.1
Distance (km)		39	108	1	22.7
Private Extension	46 (17.4)				
No of visits		6	16	1	4.5
Distance (km)		10	33	1	7.3
Public & Private Extension	88 (33.2)				
Public Extension					
No of visits		3	16	1	5.1
Distance (km)		38	110	1	19.0
Private Extension					
No of visits		4	19	1	4.9
Distance (km)		11	32	1	8.9
No Extension	31 (11.7)				

Farmers' satisfaction with:	Very Good	Good	Poor
Public Extension[1]	88 (46.8)	71 (37.8)	29 (15.4)
Private Extension[1]	73 (54.5)	55 (41.0)	6 (4.5)

[1] in parentheses are the corresponding percentage shares.

Table 2
Summary Statistics of the Variables

	Farms with:			
	Public-Extension	Private-Extension	Public & Private Extension	No Extension
Economic Data				
Output (€)	15,899	17,613	16,761	12,161
Land (stremmas)	56	43	52	50
Value of Production (€/stremma)	285	406	322	244
Labour (hours)	1,836	2,312	2,089	1,702
Intermediate Inputs (€)	2,296	2,517	2,549	2,335
Capital (€)	2,860	4,338	3,059	2,522
Farm Characteristics				
Age (years)	56	45	49	60
Education (years)	7.8	9.2	8.9	7.2
Tenancy (% of land owned)	89.1	87.6	90.2	97.7
Debts (€)	1,787	3,055	2,570	982
Subsidies (€)	4,683	2,477	4,124	3,200
Off-Farm Income (€)	4,131	4,114	4,382	3,933
Share of Production Consumed	21.5	18.6	20.8	23.5
Specialization (Herfindhal index)	0.86	0.94	0.85	0.71
Altitude (meters)	311	230	251	384
Aridity Index	0.86	0.68	0.85	0.77
Farming Intensity (dummy)	0.2	0.6	0.4	0.1
Soil Type (% of Farm Land)				
Sandy	27.8	29.5	23.9	32.0
Limestone	25.0	38.6	35.2	24.0
Marls	47.2	31.9	40.9	44.0

Table 3
Parameter Estimates of the Non-Neutral Translog Stochastic Production Frontier and Inefficiency Effects Models

Param.	Estimate	Std Error	Param.	Estimate	Std Error	Param.	Estimate	Std Error
Stochastic Frontier Model								
α_0	0.7823	(0.0821)*	α_{AO}	-0.0588	(0.0241)**	δ_{PbA}	0.0643	(0.0304)**
α_A	0.3023	(0.0371)*	α_{AC}	-0.0683	(0.0341)**	δ_{PbL}	0.0142	(0.0332)
α_L	0.2088	(0.0454)*	α_{AA}	-0.0066	(0.0323)	δ_{PbO}	-0.0521	(0.0246)**
α_O	0.1389	(0.0411)*	α_{LO}	0.2283	(0.0581)*	δ_{PbC}	-0.0802	(0.0249)*
α_C	0.1045	(0.0354)*	α_{LC}	-0.0442	(0.0680)	δ_{Pr}	0.0538	(0.0127)*
β_{Ar}	-0.1452	(0.0343)*	α_{LL}	-0.0691	(0.0332)**	δ_{PrPr}	0.0006	(0.0071)
β_{At}	0.0003	(0.0165)	α_{OC}	-0.0113	(0.0653)	δ_{PrA}	-0.1236	(0.0248)*
β_{S1}	0.0327	(0.0949)	α_{OO}	-0.0994	(0.0342)*	δ_{PrL}	-0.0182	(0.0331)
β_{S2}	0.2354	(0.0834)*	α_{CC}	0.0562	(0.0241)**	δ_{PrO}	0.0955	(0.0334)*
β_{S3}	0.1257	(0.0479)*	δ_{Pb}	0.0153	(0.0033)*	δ_{PrC}	0.1012	(0.0359)*
α_{AL}	-0.0051	(0.0609)	δ_{PbPb}	-0.0732	(0.0258)*	δ_{PbPr}	-0.0409	(0.0171)**
Inefficiency Effects Model								
ζ_0	-3.3621	(0.5902)*						
ζ_{Age}	-0.0202	(0.0021)*	ζ_{PbAge}	-0.0334	(0.0162)**	ζ_{PrAge}	0.0372	(0.0048)*
ζ_{Edu}	-0.0133	(0.0059)**	ζ_{PbEdu}	-0.0096	(0.0044)**	ζ_{PrEdu}	-0.0112	(0.0022)*
ζ_{Ten}	0.0058	(0.0030)**	ζ_{PbTen}	0.0016	(0.0123)	ζ_{PrTen}	0.0005	(0.0006)
ζ_{Dbt}	0.0038	(0.0012)*	ζ_{PbDbt}	0.0051	(0.0028)**	ζ_{PrDbt}	-0.0112	(0.0052)**
ζ_{Sub}	0.0022	(0.0024)	ζ_{PbSub}	-0.0131	(0.0060)**	ζ_{PrSub}	0.0053	(0.0089)
ζ_{Off}	0.0001	(0.0000)**	ζ_{PbOff}	-0.0044	(0.0082)	ζ_{PrOff}	0.0044	(0.0112)
ζ_{Sec}	0.0082	(0.0115)	ζ_{PbSec}	0.0084	(0.0021)*	ζ_{PrSec}	0.0107	(0.0051)**
ζ_{Spe}	0.0041	(0.0027)**	ζ_{PbSpe}	-0.0112	(0.0042)*	ζ_{PrSpe}	-0.0068	(0.0036)**
ζ_{Int}	-0.0019	(0.0008)**	ζ_{PbInt}	-0.0024	(0.0031)	ζ_{PrInt}	-0.0067	(0.0031)**
ζ_{Pb}	-0.0274	(0.0091)*	ζ_{Pr}	-0.0445	(0.0014)*	ζ_{PbPr}	-0.0089	(0.0037)**
σ^2	0.3573	(0.0382)*	γ	0.8532	(0.0641)*	λ	0.9871	(0.0414)*
$Ln(\theta)$	-98.694							

A stands for area, *L* for labour, *O* for intermediate inputs, *C* for capital, *Ar* for aridity index, *At* for altitude, *S1-S3* for three soil dummies, *Pb* for public-extension visits, *Pr* for private-extension visits, *Age* for farmers' age, *Edu* for farmers' education, *Ten* for the share of rented land, *Dbt* for farms' debts, *Sub* for subsidies, *Off* for off-farm income and, *Sec* for self-consumption level, Spe for farms' specialization and *Int* for a dummy variable to distinguish intensive farms.

*(**) indicate significance at the 1 (5) percent level.

Table 4
Model Specification Tests

Hypothesis	LR-test	Critical Value (α=0.05)
1. $\delta_{lh} = \delta_{lj} = \alpha_{jk} = 0$	98.34	$\chi^2_{21} = 32.67$
2. $\gamma = \zeta_0 = \zeta_{Pb} = \zeta_{Pr} = \zeta_{PbPr} = 0$	269.43	$\chi^2_5 = 10.37$
3. $\gamma = \delta_0 = \zeta_m = \zeta_{Pb} = \zeta_{Pr} = \zeta_{PbPr} = \zeta_{Pbm} = \zeta_{Prm} = 0 \;\; \forall m$	291.42	$\chi^2_{32} = 45.62$
4. $\zeta_0 = \zeta_m = \zeta_{Pb} = \zeta_{Pr} = \zeta_{PbPr} = \zeta_{Pbm} = \zeta_{Prm} = 0 \;\; \forall m$	241.23	$\chi^2_{31} = 43.91$
5. $\zeta_m = \zeta_{Pb} = \zeta_{Pr} = \zeta_{PbPr} = \zeta_{Pbm} = \zeta_{Prm} = 0 \;\; \forall m$	239.81	$\chi^2_{30} = 43.77$
6. $\zeta_m = 0 \;\; \forall m$	54.54	$\chi^2_9 = 16.92$
7. $\begin{matrix} \delta_{Pb} = \delta_{PbPb} = \delta_{Pbj} = \delta_{Pr} = \delta_{PrPr} = \delta_{Prj} = \delta_{PbPr} \\ \zeta_{Pb} = \zeta_{Pr} = \zeta_{PbPr} = \zeta_{Pbm} = \zeta_{Prm} = 0 \end{matrix} \;\; \forall j, m$	89.23	$\chi^2_{34} = 50.71$
8. $\zeta_{Pb} = \zeta_{Pr} = \zeta_{PbPr} = \zeta_{Pbm} = \zeta_{Prm} = 0 \;\; \forall m$	82.32	$\chi^2_{21} = 32.67$
9. $\delta_{Pb} = \delta_{PbPb} = \delta_{Pbj} = \delta_{Pr} = \delta_{PrPr} = \delta_{Prj} = \delta_{PbPr} = 0 \;\; \forall j$	58.33	$\chi^2_{13} = 22.36$
10. $\delta_{Pb} = \delta_{PbPb} = \delta_{Pbj} = \delta_{PbPr} = \zeta_{Pb} = \zeta_{Pbm} = \zeta_{PbPr} = 0 \;\; \forall j, m$	65.16	$\chi^2_{18} = 28.87$
11. $\delta_{Pr} = \delta_{PrPr} = \delta_{Prj} = \delta_{PbPr} = \zeta_{Pr} = \zeta_{Prm} = \zeta_{PbPr} = 0 \;\; \forall j, m$	72.35	$\chi^2_{18} = 28.87$
12. $\zeta_{Pb} = \zeta_{PbPr} = \zeta_{Pbm} = 0 \;\; \forall m$	34.54	$\chi^2_{11} = 19.67$
13. $\delta_{Pb} = \delta_{PbPb} = \delta_{Pbj} = \delta_{PbPr} = 0 \;\; \forall j$	23.34	$\chi^2_7 = 14.07$
14. $\zeta_{Pr} = \zeta_{PbPr} = \zeta_{Prm} = 0 \;\; \forall m$	41.23	$\chi^2_{11} = 19.67$
15. $\delta_{Pr} = \delta_{PrPr} = \delta_{Prj} = \delta_{PbPr} = 0 \;\; \forall j$	22.54	$\chi^2_7 = 14.07$
16. $\delta_{Pbj} = \zeta_{Pbm} = 0 \;\; \forall j, m$	43.64	$\chi^2_{13} = 22.36$
17. $\delta_{Prj} = \zeta_{Prm} = 0 \;\; \forall j, m$	43.65	$\chi^2_{13} = 22.36$
18. $\delta_{Pbj} = 0 \;\; \forall j$	21.14	$\chi^2_4 = 9.49$
19. $\delta_{Prj} = 0 \;\; \forall j$	17.13	$\chi^2_4 = 9.49$
20. $\zeta_{Pbm} = 0 \;\; \forall m$	26.47	$\chi^2_9 = 16.92$
21. $\zeta_{\mathrm{Pr}m} = 0 \;\; \forall m$	29.15	$\chi^2_9 = 16.92$
22. $\delta_{PbPr} = \zeta_{PbPr} = 0$	9.64	$\chi^2_2 = 5.99$
23. $\zeta_{PbPr} = 0$	17.12	$\chi^2_1 = 3.84$
24. $\delta_{PbPr} = 0$	7.32	$\chi^2_1 = 3.84$
25. $\sum \alpha_j + \sum \delta_l = 1$ and $\sum \alpha_{jk} + \sum \delta_{lh} + \sum \delta_{lj} = 0$	45.23	$\chi^2_7 = 14.07$

Pb stands for public-extension visits, *Pr* for private-extension visits, *m= Age, Edu, Ten, Dbt, Sub, Off, Sec*, *Spe*, *Int* and *j = A, L, O, C.*
Note: When the null hypothesis involves the restriction of γ=0 then the LR-test statistic follows a mixed chi-squared distribution, the critical values of which are obtained from Kodde and Palm (1986, table 1).

Table 5

Frontier Production Elasticities and Returns to Scale by Extension Source

Input	Farms with: Public-Extension	Private-Extension	Public & Private Extension	No Extension
Area	0.3332 (0.0234)	0.3527 (0.0287)	0.3102 (0.0213)	0.3017 (0.0245)
Labour	0.1687 (0.0541)	0.1814 (0.0609)	0.1772 (0.0572)	0.1395 (0.0425)
Intermediate Inputs	0.1243 (0.0410)	0.1175 (0.0387)	0.1161 (0.0339)	0.1321 (0.0367)
Capital	0.1072 (0.0256)	0.0892 (0.0279)	0.1012 (0.0298)	0.1777 (0.0309)
Public-Extension	0.0409 (0.0103)	-	0.0554 (0.0123)	-
Private-Extension	-	0.1023 (0.0232)	0.0725 (0.0245)	-
Returns to Scale	0.7743 (0.1093)	0.8431 (0.1385)	0.8326 (0.1532)	0.7510 (0.1424)

In parentheses are the corresponding standard errors. All coefficients are statistically significant at the 1 percent level.

Table 6

Frequency Distribution and Minimal Width Intervals of Output-Oriented Technical Efficiency by Extension Source

Efficiency (%)	Farms with: Public-Extension	Private-Extension	Public & Private Extension	No Extension	All Farms
<30	0	0	0	0	0
30-40	1	0	0	3	4
40-50	13	2	3	9	27
50-60	10	3	4	8	25
60-70	42	13	17	7	79
70-80	23	17	32	4	75
80-90	4	7	21	0	33
90-100	7	4	11	0	22
N	100	44	88	31	265
Mean	66.72	72.52	76.57	54.24	67.51
StdDeviation	10.20	10.91	16.52	9.85	11.87
Min	38.53	40.31	46.81	33.52	33.52
Max	99.83	96.12	99.92	75.36	99.92

Table 7

Statistical Testing and 95 percent Confidence Intervals of the Differences in the Mean Output-Oriented Technical Efficiency Between Farms with Different Extension Source

Hypothesis	$\overline{TE}_i^O - \overline{TE}_j^O$	t-value	95% Confidence Intervals	
			Lower	Upper
$H_0: \overline{TE}_{Pr}^O - \overline{TE}_{Pb}^O = 0$	5.80	2.997*	1.96	9.64
$H_0: \overline{TE}_{Bt}^O - \overline{TE}_{Pb}^O = 0$	9.85	4.840*	5.81	13.89
$H_0: \overline{TE}_{Pb}^O - \overline{TE}_{N}^O = 0$	12.48	6.112*	8.43	16.53
$H_0: \overline{TE}_{Bt}^O - \overline{TE}_{Pr}^O = 0$	4.05	1.681***	-8.83	0.73
$H_0: \overline{TE}_{Pr}^O - \overline{TE}_{N}^O = 0$	18.28	7.568*	13.46	23.10
$H_0: \overline{TE}_{Bt}^O - \overline{TE}_{N}^O = 0$	22.33	8.945*	17.38	27.28

Pb stands for public-extension visits, *Pr* for private-extension visits, *Bt* for both kinds of extension and *N* for no-extension. * (***) indicates statistical significance at the 1(10) percent level.

The *t-test* and the associated *confidence intervals* are computed from the following formulas: $t = \frac{\overline{TE}_\rho^O - \overline{TE}_\kappa^O}{\sqrt{\left(Var\left[TE_\rho^O\right]/n_\rho\right) + \left(Var\left[TE_\kappa^O\right]/n_\kappa\right)}}$ and $\left(\overline{TE}_\rho^O - \overline{TE}_\kappa^O\right) \pm t_{v,0.025}\sqrt{\frac{Var\left[TE_\rho^O\right]}{n_\rho} + \frac{Var\left[TE_\kappa^O\right]}{n_\kappa}}$ $\forall \rho \neq \kappa$ where $v \approx n_\rho + n_\kappa - 2$ is the associated number of the degrees of freedom, n_ρ and n_κ is the number of farms in the ρ^{th} and κ^{th} sub samples, respectively, and $\rho, \kappa = Pb, Pr, Bt, N$.

Table 8

Total (Direct and Indirect) Effect of Public and Private Extension Services on Farms' Productivity

	Farms with:		
	Public-Extension	Private-Extension	Public & Private Extension
Total Effect	0.0468	0.1088	0.1437
	(0.0105)	(0.0236)	(0.0302)
Direct Effect	0.0409	0.1023	0.1279
	(0.0103)	(0.0232)	(0.0236)
Indirect Effect	0.0059	0.0065	0.0158
	(0.0010)	(0.0016)	(0.0024)

In parentheses are the corresponding standard errors. All coefficients are statistically significant at the 1 percent level.

Table 9

Indirect Effects of Farm Specific Structural and Demographic Characteristics on Farms' Output-Oriented Technical Inefficiency Levels by Extension Source

Farm Specific Characteristic ($x10^2$)	Farms with: Public-Extension	Private-Extension	Public & Private Extension	No Extension
Age	(+)	(-)	(+)	(+)
Education	(+)	(+)	(+)	(+)
Tenancy	0	0	0	(-)
Debts	(-)	(+)	(-)	(-)
Subsidies	(+)	0	(+)	0
Off-Farm Income	0	0	0	0
Self-Consumption	(-)	(-)	(-)	0
Specialization	(+)	(+)	(+)	(-)
Farming Intensity	(+)	(+)	(+)	0

Endnotes

[1] These changes were initiated by the general perception that public extension networks are too inflexible and unresponsive, with high cost in providing extension services to farmers and adequately addressing their needs.

[2] Output-oriented measures of technical inefficiency are more appropriate in agricultural frontier modeling, since input choices are made prior to farm production.

[3] Since u is non-positive, the random term ω must be truncated from above.

[4] Huang and Liu in their original formulation used the parameterization of the likelihood function suggested by Aigner, Lovell and Schmidt and the predictor developed by Jondrow *et al*..

[5] This and the following hypotheses are tested using the conventional generalized likelihood-ratio (LR) test. The test approximately follows a *chi-squared* distribution except in the case where the null hypothesis involves the restriction that γ=0 (Coelli). Then, it follows a *mixed chi-squared* distribution the critical values of which are obtained from Kodde and Palm.

[6] Output elasticity is a local directional measure evaluated at a point on the production frontier (Førsund). Thus, the second-term on the RHS of (3) is not included in (8) since at the frontier it implies that u_i=0.

[7] Notice that only the output elasticity of private extension is taken into account in calculating returns to scale as public extension involves no cost for farms.

[8] Data on private extension outlets were taken from the National Statistical Service of Greece (NSSG, 1996).

[9] The Herfindhal index is defined as: $D_{int} = \sum_p \left(y_p^S\right)^2$ where y_p^S is the share of p^{th} output in total farm production (Llewelyn and Williams). A value of D_{int} close to unity indicates specialization, whereas smaller values reflect increased diversification.

[10] If the ratio-parameter, γ, equals zero, the model reduces to an average response function in which the variables of the inefficiency effects model can be included directly in the production function. In this case the constant (ζ_0) as well as the first-order parameters associated with extension variable (ζ_{Pb} and ζ_{Pr}) and the interaction term among them (ζ_{PbPr}) cannot be identified as they are already included in the production frontier model. Thus, the number of restrictions for the chi-squared test statistic in the second hypothesis of Table 4 is five.

[11] It should be noted that the range of the interval estimates is affected by the variables introduced in the inefficiency effects model as they influence the conditional mean of *u* and therefore the spread of the limits of technical inefficiency (Hjalmarsson, Kumbhakar and Heshmati).