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Innovation and Profit Efficiency in Organic Farming

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Abstract: This paper measures the contribution of innovations in profit efficiency of organic farmers. By constructing an innovation variable, primary cross section data on organic olive enterprises from a Greek region is used in the application of the stochastic frontier profit function. Farmers are classified into groups according to their innovative 'profile'. Profit efficiency scores are estimated and profit efficiency differences among farmer groups are computed, as well as the corresponding profit loss. Results indicate that adoption of innovations results in the increase of profit efficiency. More innovative farmers perform better than less innovative ones regarding both profit efficiency and profit loss.

Key words: Innovations · Total factor productivity · Organic farming · Olive · Greece

INTRODUCTION

According to a generally acceptable definition, innovation is "an idea, technique, or object that becomes acceptable as innovation from an individual or other unit of adoption" [1]. During the first decades after the 2nd world war, many innovations were adopted by Greek farmers (pesticides, tractors, modern irrigation systems, improved varieties of plants and animal breeds etc.), intensifying their farms. However, the permanently small farm size was responsible for this intensification. At the same time, labour in agriculture marked a continuous reduction and in 1990, fell below the half of the 1960 corresponding level, while the average farm size increased more than double of its size in 1960. As a result, it can be said that a partial substitution of human labour by agricultural machinery and other forms of capital took place. This substitution involved to a large extent the modernisation and the growth of Greek agriculture. The former is expressed by the diffusion of several innovations, while the latter is proved by the increase, by 4.5 times from 1960 to 2004, in per worker gross value added (GVA) [2].

The main objectives of this study are to measure the contribution of innovations in profit efficiency and profit loss of organic olive farmers. The key point is the use of an innovation variable to proxy technical difference among farmer groups. This is done by applying the stochastic frontier profit function in a cross section dataset. The paper is structured as follows: next session presents the concept of profit efficiency measurement, introduces the innovation index, innovation groups and innovation variable. The study area is discussed next, the empirical model and results of the study. Finally, some policy implications are drawn along with the conclusion.

METHODOLOGY

Profit Efficiency Measurement: In this study, a profit function framework is used for the estimation of farm-specific efficiency and decomposition of TFP difference. The concept of profit efficiency combines technical and allocative efficiency [3]. The stochastic profit function is defined as:

$$\pi_i = f(P_{ij}, Z_{ik}) \cdot e^{\xi_i}$$

Where π is normalized profit of farm i, defined as gross revenue less variable cost, divided by farm-specific output price; j^{th} is normalized price (defined as the price of that input divided by farm-specific output price) of the j^{th} variable input used by the i^{th} farm; Z_{ik} is the level of the k^{th} fixed factor of the i^{th} farm; ξ_i is an error term; and $i = 1,\ldots,n$ is the number of farms in the sample.

Following Kmenta [4] (for the production function) and Ali and Flinn [5] (for the profit function), the error term ξ_i is assumed to have a consistent with the frontier concept behaviour:

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Table 1: Innovations and corresponding traditional methods in organic olive farming

	Fieldwork	Traditional method	Innovation
1	Pruning with:	hand prunes	pneumatic and electric prunes
2	Pruning of thick branches with:	saw	chain-saw
3	Collection of cut branches:	by hand	with a fork-shaped tool for tractor
4	Treatment of pruning remains	burning	embodiment in the soil
5	Irrigation method	streaming water	Drop irrigation
6	Fertilizers	manure	compost, bio-fertilizers or plant extracts
7	Fertilization	unconsidered	ensued from soil analysis
8	Trapping of olive fruit fly with:	homemade traps based on ammonia	McPhail-type liquid traps, yellow sticky panel traps
9	Spraying accessory	pesticide Spray hose for tractor	pressurized containers for tractor
10	Harvesting of olive fruits with:	handheld combs or long sticks	trunk shakers, pneumatics branch shakers, Vibration type olive harvesters

$$\xi_i = v_i - u_i$$

v_i is the independently and identically distributed $N(0, \sigma^2_v)$ two sided, symmetric error term. It stands for the usual random effects, omitted explanatory variables, statistical noise and measurement errors.

u_i is the non-negative one-sided error term standing for the inefficiency of the farm. It represents the profit loss, resulting from farmer's failure in achieving maximum possible profit, demonstrated by the profit frontier. It is assumed to be a function of variables that explain inefficiency of the farm. Statistically, it is assumed to be independently distributed as truncations at zero of the normal distribution with mean $\mu_i = \delta_0 + \sum_d \delta_d W_{di}$ and variance σ_u^2, where W_{di} is the dth variable explaining inefficiency of farm i and δ_0 and δ_d are parameters to be estimated.

Innovation Index, Innovation Groups, Innovation Variable and High-tech Capital: For the purposes of this study, a measure of farmers' innovativeness had to be applied; one that reflects the number of innovations adopted by organic olive farmers. To this end, an innovation index was constructed and a value was computed for each farmer. Innovation index was build as follows: In organic farming of olive trees, some innovations (10 detected) are diffused, more or less, among farmers. These innovations as well as the corresponding traditional methods are listed in Table 1. Each innovation adds one point to the index, apart from type of fertilizers, which can add up to two points, in the case of using at least two different type of innovative fertilizer and no manure at all.

Innovation index takes continuous values between 0 and 11 because some innovations (namely fertilizers, fertilization, harvesting, treatment of pruning, irrigation, olive fruit fly trapping) are applied not necessarily on the whole olive enterprise, but on a portion of it. So, this innovation does not add 0 or 1 in the index but a decimal, which is a divisia index of 0 and 1, weighted by the area portions. Derived values of innovation index are separated into 6 equivalent groups, each one of those measuring 11/6. Thus farmers characterized by an innovation index value between 0 and 11/6 are the 'laggards' according to Rogers [6] classification, whereas those scoring between 5.11/6 and 11 are the 'innovators'. Intermediate classes follow a similar interpretation. These are the six 'innovation groups' that total farmers' sample can be segregated into. Thus an 'innovation variable' can be defined as to take discrete values from 1 to 6 in correspondence with the innovation group. This is a dummy variable which meets Kmenta's [4] qualifications for dummy variables and will be used as a proxy of technical progress.

The Study Area: Large olive production areas in Greece are located throughout the country. That makes primary data collection, which will encompass the whole country, an extremely difficult task. Consequently, a study based on primary data is likely to focus on one of the following olive production areas: Central Greece, Peloponnesus, Ionian Sea islands, Aegean Sea islands, Crete and Northern Greece. This study uses primary collected data from four prefectures of Northern Greece region, accounting for the 97.8% of olive planted area of the region [7]. They are: Xalkidiki, Kavala, Thessaloniki and Serres prefectures. In these prefectures, one can identify three different agro-ecological areas of olive cultivation. In Thessaloniki, Serres and the continental part of Kavala prefecture, olive trees are characterized by their early age, located in semi-mountainous areas. In Xalkidiki, there are many mid-aged trees located in mountainous and semi-mountainous areas. Finally, in Thassos Island (in the Kavala prefecture), olive trees are mostly large and over-aged, facing a typical Mediterranean climate. Since farmers located in different areas face different transportation costs and market access, the effort made to collect data from many villages in these three areas ensures variation in input and output prices, necessary for the profit function application.

The farm-survey conducted among olive producers by using a properly constructed questionnaire during the summer of 2006 and pertains to the growing seasons 2004 and 2005. However, data has a cross-section form because each data element is a two-year average. This was done in order to eliminate an attribute of the olive tree; the rotation of years with large and low production. 177 farmers were included in the survey. We did not follow any random sampling method. Instead we tried to enrich the sample with as more olive farmers as possible. Considering that population in the study area numbers 258 olive farmers, 68.6% of those were included in the sample. Collected data pertains to socio-economic characteristics of farmers, agro-ecological parameters and on prices and quantities of inputs and outputs of the farm enterprises. Yet, in the following analysis, data refers only to the olive enterprise and not in the whole farm, that is, value of quasi-fixed inputs, employed by many enterprises of a farm, was allocated among the enterprises of the farm, according to the contribution of the enterprises in the configuration of total farm revenue.

The Empirical Model: Let $\pi = \pi(p, w; z, I)$ be a well-defined restricted profit function, where ð denotes the variable profit, *p* and *w* the output and input prices respectively, *z* the value of the quasi-fixed inputs and *I* the innovation variable that proxies technical difference among farmer groups. The corresponding production function regards the combination of *I* variable and *k* quasi-fixed inputs to produce *j* multiple outputs.

The restricted frontier profit function was chosen to have the translog form because it provides a good second-order Taylor series local approximation to the profit function without imposing prior restrictions. We follow the single stage estimation procedure, introduced by Battese and Coelli [8] in order to increase the efficiency of estimation. Dropping the property-specific subscripts to avoid confusion, the translog restricted frontier profit function becomes:

$$\begin{aligned}\ln\pi = {} & \alpha_0 + \sum_{i=1}^{2}\beta_i \ln w_i + \sum_{k=1}^{4}\gamma_k \ln z_k + \delta_1 I \\ & + \frac{1}{2}\sum_{i=1}^{2}\sum_{l=1}^{2}\beta_{il}\ln w_i \ln w_l + \frac{1}{2}\sum_{k=1}^{4}\sum_{m=1}^{4}\gamma_{km}\ln z_k \ln z_m \\ & + \frac{1}{2}\delta_2 I^2 + \sum_{i=1}^{2}\sum_{k=1}^{4}\zeta_{ik}\ln w_i \ln z_k + \sum_{i=1}^{2}\eta_i \ln w_i I \\ & + \sum_{k=1}^{4}\theta_k \ln z_k I + \sum_{r=1}^{13}\varepsilon_r D_r + v - u\end{aligned}$$

and $u = \lambda_0 + \lambda_1 I$, where:

ð	=	Normalized profit per stremma (10 stremmas = 1 Hectare, henceforth str.) defined as gross revenue less variable cost, divided by output price
w_L	=	Wage of labor normalized with respect to output price
w_M	=	Tornquist index of materials' price normalized with respect to output price. This index is computed as the weighted geometric average of the price relatives, using arithmetic averages of the value shares of materials as weights. The materials are: fertilizers, copper-based substance for plant-protection and traps for olive fruit fly (Dacus olea)
z_H	=	Value of high-tech capital per str. This is defined as the value of tools and machines related to the capital-embodied innovations 1-5 and 9-10 of Table 1.
z_N	=	Value of non-high-tech capital per str., defined as the value of total capital less z_H
z_R	=	Land value per str. (paid or implicit rental for rented-in and privately-owned land respectively)
z_T	=	Value of tree capital per str.
É	=	innovation variable that corresponds to the innovation group (1 for traditional farmers, 6 for very innovative ones, 2-5 for intermediate groups)
v	=	Two sided random error
u	=	one sided half-normal error
D_r	=	Dummies accounting for the following parameters: location, plantation density, percentage of irrigated land, number of years since the adoption of organic cultivation of olive trees, age of trees, climatic conditions, soil quality and mean slope of the fields arameters to be estimated.

We chose to include in the efficiency effects equation no more explanatory variables but the innovation variable (*I*), in order to focus in its effect on efficiency. Yet, farm-specific variables enter the model as dummies, likely to affect normalized profit. Regarding output price, which serves for normalization, is a Tornquist index of prices of table olives and olive oil, computed as weighted geometric average of the price relatives, using arithmetic averages of the value shares of table olives and olive oil as weights.

RESULTS

Selected characteristics of the sample farms are summarized in Table 2. Mean olive enterprise size is 63.5 str. showing considerable variation (ranging from 0.7 to 430.2 str.). In addition, mean olive enterprise size of farmers in innovation groups 5 and 6 (innovative farmers) is almost double of that of the other 4 categories. Variable profit is steadily increasing, from 90.81 €/str in group 1 to 204.68 €/str in group 6, with mean value 128.09 €/str.

Table 2: Summary statistics

	Innovation group									
Variables	1	2	3	4	5	6	Mean	St. Dev.	Min.	Max.
Olive enterprise size and profit function netputs										
Olive enterprise size (Str.)	34.95	59.85	47.82	46.74	102.74	111.04	63.5	70.96	0.7	430.2
Variable profit (€/str.)	90.81	106.63	122.32	129.18	140.65	204.68	128.09	82.38	1.63	386.72
Output price (Tornquist index)	3.694	3.609	3.631	4.039	3.667	3.919	3.747	0.581	2.5	5.5
Labour wage (€/hour)	4.428	4.549	4.546	4.354	4.235	4.445	4.435	0.655	2.75	6.75
Price of materials (Tornquist index)	1.628	1.794	1.828	1.721	1.722	1.904	1.761	0.47	0.938	2.838
Value of high-tech capital (€/str.)	5.98	10.46	14.89	22.92	22.72	25.06	16.17	17.13	0.02	87.22
Value of non-high-tech capital (€/str.)	53.86	64.61	51.83	55.99	76.4	64.79	60.34	45.21	7.49	195.58
Land value (€/str.)	25.66	24.1	24.85	28.31	25.92	31.81	26.49	8.26	5.36	61.87
Value of tree capital (€/str.)	73.34	65.3	56.26	63.49	61.17	63.63	63.9	27.07	27.8	133.31
Innovation variable	1	2	3	4	5	6				
Farm specific variables										
Location (%)										
Serres-Kavala-Thessaloniki							16.95			
Xalkidiki							48.59			
Thassos							34.46			
Plantation density (number of trees per str.)	21.56	19.65	17.73	20.01	17.95	21.54	19.67	7.43	6.93	38.64
Index of the percentage of irrigated land	2.342	2.25	2.35	2.496	2.629	2.668	2.437	0.416	2	3
Years of organic production before 2006 (%)										
1							38.98			
2							13.56			
3 or more							47.46			
Age capacity of trees (% of years in full production capacity; maximum years set at 30 for non-irrigated, 50 for irrigated)	55.18	64.56	79.88	70.41	70.68	69	68.28	32.61	2	100
Climatic conditions in 2004 and 2005 (%)										
Favourable for olive trees							42.37			
Moderate							22.03			
Unfavourable for olive trees							35.59			
Soil quality (%)										
Favourable for olive trees							26.55			
Moderate							52.54			
Unfavourable for olive trees							20.9			
Mean slope of fields (%)										
Steep (>15%)							17.51			
Gentle (5%<…<15%)							49.15			
Almost plane surface (<5%)							33.33			

Source: Study's result

Table 3: Maximum likelihood estimates

Variables and labels	Parameters	Coefficients	t-ratio
Stochastic profit frontier			
Constant	α_0	-0.933	-2.152**
Normalized labor wage ($\ln w_L$)	β_L	2.096	7.26***
Normalized materials' price ($\ln w_M$)	β_M	-2.374	-7.158***
Value of high-tech capital ($\ln z_H$)	γ_H	0.344	2.251**
Value of non-high-tech capital ($\ln z_N$)	γ_N	-0.317	-0.96
Land value ($\ln z_R$)	γ_R	-2.373	-7.934***
Value of tree capital ($\ln z_T$)	γ_T	0.915	1.794*
Innovation variable ($\acute{E}$)	δ_1	0.125	2.205**
$1/2(\ln w_L)^2$	β_{LL}	-1.109	-4.47***
$1/2(\ln w_m)^2$	β_{MM}	-3.053	-6.84***
$1/2(\ln z_H)^2$	γ_{HH}	0.018	0.76
$1/2(\ln z_N)^2$	γ_{NN}	0.077	2.077**
$1/2(\ln z_R)^2$	γ_{RR}	-0.297	-3.028***
$1/2(\ln z_T)^2$	γ_{TT}	-0.814	-2.324**
$1/2\ I^2$	δ_2	0.04	1.969*
$\ln w_L \bullet \ln w_M$	β_{LM}	2.154	7.516***
$\ln w_L \bullet \ln z_H$	ζ_{LH}	0.793	11.19***
$\ln w_L \bullet \ln z_N$	ζ_{LN}	-0.637	-3.414***
$\ln w_L \bullet \ln z_R$	ζ_{LR}	0.772	2.524**
$\ln w_L \bullet \ln z_T$	ζ_{LT}	-0.319	-0.507
$\ln w_L \bullet I$	η_L	-0.497	-8.942***
$\ln w_M \bullet \ln z_H$	ζ_{MH}	0.318	3.924***
$\ln w_M \bullet \ln z_N$	ζ_{MN}	0.552	4.617***
$\ln w_M \bullet \ln z_R$	ζ_{MR}	-2.091	-5.451***
$\ln w_M \bullet \ln z_T$	ζ_{MT}	-0.02	-0.128
$\ln w_M \bullet I$	η_M	0.14	2.546**
$\ln z_H \bullet \ln z_N$	γ_{HN}	0.002	0.133
$\ln z_H \bullet \ln z_R$	γ_{HR}	-0.307	-7.575***
$\ln z_H \bullet \ln z_T$	γ_{HT}	-0.019	-0.559
$\ln z_H \bullet I$	θ_H	0.029	1.78*
$\ln z_N \bullet \ln z_R$	γ_{NR}	0.234	5.281***
$\ln z_N \bullet \ln z_T$	γ_{NT}	0.487	4.919***
$\ln z_N \bullet I$	θ_N	-0.071	-3.918***
$\ln z_R \bullet \ln z_T$	γ_{RT}	0.376	1.894*
$\ln z_R \bullet I$	θ_R	0.253	7.87***
$\ln z_T \bullet I$	θ_T	-0.212	-12.11***
Location (0 for Serres-Kavala-Thessaloniki, 1 for Xalkidiki)	ε_1	-0.491	-5.214***
Location (0 for Serres-Kavala-Thessaloniki, 1 for Thassos)	ε_2	-0.317	-2.963***
Plantation density	ε_3	0.268	5.295***
Index of the percentage of irrigated land	ε_4	0.099	2.284**
Year of adopting organic cultivation of olive trees (0 for 2003 or before, 1 for 2004)	ε_5	0.233	3.339***
Year of adopting organic cultivation of olive trees (0 for 2003 or before, 1 for 2005)	ε_6	0.07	1.968*
Age of trees (index; logarithm of years in full production capacity)	ε_7	0.209	6.043***
Climatic conditions in 2004 and 2005 (0 for unfavorable, 1 for moderate)	ε_8	0.174	6.418***
Climatic conditions in 2004 and 2005 (0 for unfavorable, 1 for favorable)	ε_9	0.124	3.748***
Soil quality (0 for unfavorable, 1 for moderate)	ε_{10}	0.251	6.604***
Soil quality (0 for unfavorable, 1 for favorable)	ε_{11}	0.487	6.237***
Mean slope of the fields (0 for steep, 1 for gentle)	ε_{12}	0.05	1.147
Mean slope of the fields (0 for steep, 1 for almost plane surface)	ε_{13}	-0.054	-2.687***
Inefficiency effects			
Constant	λ_0	1.77	9.31***
Innovation variable ($\acute{E}$)	λ_1	-1.047	-16.82***
Variance Parameters			
Sigma-squared ($\sigma^2 = \sigma_v^2 + \sigma_u^2$) = 1.654, t-stat = 36.63			
Gamma ($\gamma = \sigma_u^2 / \sigma^2$) = 0.999, prob. = 0.000			
Log likelihood function = -102.9			

*** Significant at 1% level

** Significant at 5% level

* Significant at 10% level

Value of high-tech capital is also increasing, from 5.98 €/str in group 1 to 25.06 €/str in group 6, while innovation groups 4 and 5 face similar figures. In addition, more innovative farmers (groups 4, 5 and 6) have more and more percentage of irrigated land, compared to the first groups (1, 2 and 3). This shows that innovative farmers are increasingly table olive producers, while less innovative farmers are mostly olive oil producers. Totally, the profile of farmers of innovation groups 5 and 6 is quite different from that of innovation groups 1 to 3. The former cultivate a considerably larger olive enterprise, highly mechanized, oriented towards the production of table olives. These attitudes result in higher profit per str., especially for innovation group 6. The profile of farmers of innovation group 4 has elements of both aforementioned profiles.

The maximum-likelihood estimates (MLE) of the parameters of the stochastic frontier profit function are presented in Table 3. Results were obtained using the program Frontier 4.1 [9].

Theoretical properties of the restricted profit function were either imposed, or satisfied. Symmetry was imposed by restricting $\beta_{il} = \beta_{li}$ *and* $\gamma_{km} = \gamma_{mk}$. Linear homogeneity in profit and input prices was imposed by normalization with output price. In order to test for the monotonicity condition of the profit function, Hotelling's Lemma was applied and input profit shares were obtained, as follows:

$$S_i = \beta_i + \beta_{il} \ln w_l + \sum_{k=1}^{4} \zeta_{ik} \ln z_k + \eta_i I$$

The monotonicity condition holds for both input prices in the sample mean, that is, input profit shares are negative.

In a restricted profit function, quasi-fixed input shares must be positive, as well [10]. They are computed as follows:

$$M_k = \gamma_k + \gamma_{km} \ln z_m + \sum_{i=1}^{2} \zeta_{ik} \ln w_i + \theta_k I$$

3 out of 4 quasi-fixed input shares are found to meet this requirement. The only quasi-fixed input share that is negative is that of tree capital. However, this is not surprising. On the contrary, this is the expected sign, if we consider the construction of this variable. Tree capital is computed as the initial value of the olive grove minus total depreciation. Taking into consideration the limit of 30 (50) years, imposed as the maximum life cycle of irrigated (non-irrigated) olive trees, many age-long olive groves are in their full capacity period during the 30th (50th) year, regarded as last productive season. Nevertheless, in this year tree capital takes its lowest value, as total depreciation has reached its maximum value. That is, tree capital is negatively correlated with productivity of olive trees and hence, with profitability as well. As a result, the computed negative sign is the correct one, as far as the tree capital is concerned.

By applying maximum likelihood estimation, apart from the parameters, the stochastic frontier and the inefficiency effects, $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2 / \sigma^2$ are obtained. The value of is bounded between 0 and 1. Estimated value of γ (0.999) is very close to 1, indicating that inefficiency effects are affecting much more total variance σ^2 than random noise, in the estimated profit function. However, this can be subjected to statistical verification, using the Likelihood Ratio test statistic.

The likelihood-ratio (LR) test statistic (λ = -2{log[Likelihood (H_0)]-log[Likelihood (H_1)]}) is a chi-squared $\varkappa_v^2$ based test and í takes the zero value for the null hypothesis [11]. This test was conducted in order to test several other hypotheses as well. These hypotheses concern the validity and correctness of using the one stage efficiency model and the specific econometric specification instead of alternatives (the results of all LR tests are listed in Table 4). First of all, the null hypothesis was $\lambda_0 = \lambda_1 = 0$, which was rejected at the 1% level of significance. Consequently, there are significant effects from inefficiency in the restricted frontier profit function model that cannot be ignored, assuming a deterministic form for the function and estimating it by a corresponding method (e.g. by OLS). Furthermore, hypothesis H_0: $\lambda_0 = \lambda_1 = 0$ was rejected at the 1% level of significance, implying that there are significant inefficiency effects in the stochastic profit function model. Hence, the choice of the one stage model of Battese and Coelli [8] is preferred to the alternative model of two stages. Finally, alternative econometric specifications of the stochastic frontier profit function were tested. They concern different definition of capital value, treated though as quasi-fixed input in each case. The null hypothesis (H_0) regarded:

- The total value of capital (Z_{HNRT}).
- Capital value, divided in high-tech capital and non high-tech capital value (Z_H-Z_{NRT}). The definition of the former is as described in the 'Empirical Model' section, whereas the latter includes the value of the remaining three quasi-fixed variables.
- Capital value, divided in high-tech capital, non high-tech capital and land value along with tree capital value (Z_H-Z_N-Z_{RT}).

Table 4: Results of Likelihood Ratio tests

No.	Null hypothesis (H_0)	Alternative (H_1)	λ	d.f.	Critical value*	Result
1	$\gamma = 0$	$\gamma > 0$	123.13	1	6.63	reject H_0
2	$\lambda_0 = \lambda_1$	$\lambda_0 \neq 0$, $\lambda_1 \neq 0$	40.59	8	20.1	reject H_0
3	Z_{HNRT}	Z_H-Z_N-Z_R-Z_T	66.15	15	30.6	reject H_0
4	Z_H-Z_{NRT}	Z_H-Z_N-Z_R-Z_T	54.24	21	38.9	reject H_0
5	Z_H-Z_N-Z_{RT}	Z_H-Z_N-Z_R-Z_T	40.28	2	9.21	reject H_0
6	Cobb-Douglas	Translog	100.78	28	48.3	reject H_0

*($\varkappa_v^2$) at 1% level of significance [from Kodde and Palm (1986)]

Table 5: Frequency distribution of enterprise-specific profit efficiency estimates*

Efficiency	Innovation group 1			Innovation group 2			Innovation group 3			Innovation group 4			Innovation group 5			Innovation group 6			total sample		
estimate (%)	F.	P.	C.P.	F.	P.	C.P.	F.	P.	C.P.	F.	P.	C.P.	F.	P.	C.P.	F.	P.	C.P.	F.	P.	C.P.
0-10	6	17.65	17.65	3	10.00	10.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	9	4.61	4.61
10.01-20	7	20.59	38.24	1	3.33	13.33	0	0.00	0.00	2	7.14	7.14	1	3.85	3.85	0	0.00	0.00	11	5.82	10.43
20.01-30	3	8.82	47.06	5	16.67	30.00	7	19.44	19.44	3	10.71	17.86	2	7.69	11.54	1	4.35	4.35	21	11.28	21.71
30.01-40	3	8.82	55.88	5	16.67	46.67	6	16.67	36.11	3	10.71	28.57	1	3.85	15.38	2	8.70	13.04	20	10.90	32.61
40.01-50	3	8.82	64.71	0	0.00	46.67	2	5.56	41.67	4	14.29	42.86	3	11.54	26.92	0	0.00	13.04	12	6.70	39.31
50.01-60	4	11.76	76.47	3	10.00	56.67	3	8.33	50.00	1	3.57	46.43	1	3.85	30.77	1	4.35	17.39	13	6.98	46.29
60.01-70	0	0.00	76.47	3	10.00	66.67	2	5.56	55.56	3	10.71	57.14	3	11.54	42.31	3	13.04	30.43	14	8.48	54.76
70.01-80	2	5.88	82.35	3	10.00	76.67	2	5.56	61.11	1	3.57	60.71	0	0.00	42.31	0	0.00	30.43	8	4.17	58.93
80.01-90	2	5.88	88.24	2	6.67	83.33	4	11.11	72.22	4	14.29	75.00	1	3.85	46.15	2	8.70	39.13	15	8.41	67.35
90.01-100	4	11.76	100.00	5	16.67	100.00	10	27.78	100.00	7	25.00	100.00	14	53.85	100.00	14	60.87	100.00	54	32.65	100.00
Total	34	100		30	100		36	100		28	100		26	100		23	100		177	100	
Average Efficiency(%)		40.41			52.64			62.74			62.56			74.65			83.43			61.15	
St. Dev.		31.98			31.49			29.37			31.56			29.74			24.13			32.29	

* F. = Frequency in the sample, P. = Percentage within the innovation group, C.P. = Cumulative Percentage within the innovation group

Hypothesis H_1 represent capital value, divided in high-tech capital, non high-tech capital, land and tree capital value (Z_H-Z_N-Z_R-Z_T). Hypotheses H_0 were all rejected at the 1% level of significance, implying that capital value, taken as in hypotheses H_1, is the more appropriate form to enter the econometric specification of the stochastic frontier profit function. Finally, hypothesis H_0 set to be the Cobb-douglas specification instead of the translog, using the Z_H-Z_N-Z_R-Z_T capital definition. This hypothesis was also rejected at the 1% level.

Innovation, as a technology index, has a significant (at 5% level) positive effect on normalized profit. Furthermore, innovation variable has a significant (at 10% level) positive effect on the increase rate of normalized profit, in more innovative farmers. Consequently, adoption of innovations increasingly enhances profitability of the olive enterprise. Remember, however, that the construction of innovation variable is done with regard to innovations in quasi-fixed as well as in variable inputs. As a result, this measure reveals the contribution of farmer's innovative behavior in normalized profit as a whole, without differentiation between the types of adopted innovations. Such a differentiation can be done by examining the contribution of the high-tech capital alone. This type of capital refers only in innovations embodied in the quasi-fixed capital. Value of high-tech capital has a significant (at 5% level) positive effect on normalized profit as well. This means that by increasing investment in high-tech capital, farmers can increase profitability of their olive enterprise.

The distribution of profit efficiency estimates for the six innovation groups is shown in Table 5 and Fig. 1. The average profit efficiency is 61.15%, ranging from 1.01 to 99.98%, considerably increased in more innovative farmers and more concentrated in innovation group 6. Other studies have reported that low efficiency levels and wide efficiency variation as well (see [3], [12]). In spite of the wide range, skewness of frequency percentage differs among innovation groups. Innovation groups 1 to 3 dominate in profit efficiency estimates from 0 to 60, whereas innovation groups 4 to 6 prevail in estimates from 60 to 100 (Fig. 1). Almost 54% of farmers of innovation group 5 and 61% of innovation group 6 achieve profit efficiency between 90% and 100%. These indicate that there is substantial scope for improvement for the average olive enterprise, by improving its technical and allocative

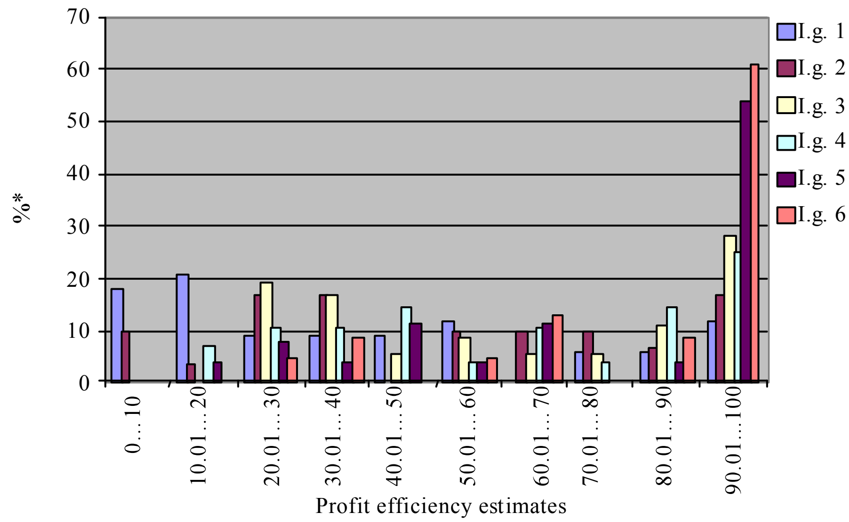

Fig. 1: Histogram of profit efficiency estimates for the six innovation groups
* Percentage of the frequency of profit efficiency estimates within an innovation group

Table 6: Profit loss among innovation groups due to inefficiency

	Average actual profit (€/str.)	Average profit efficiency	Average estimated profit loss (€/str.)
I.g. 1	90.81	40.41	216.52
I.g. 2	106.63	52.64	134.79
I.g. 3	122.32	62.74	85.31
I.g. 4	129.18	62.57	84.73
I.g. 5	140.65	74.65	63.02
I.g. 6	204.68	83.43	39.77
Total sample	128.09	61.15	109.62

profit efficiency and this perspective is ever broader for less innovative farmers. The increase on profits can reach 38.85% for the mean enterprise, whereas for less innovative farmers, namely innovation groups 3, 2 and 1, the increase can rise up to 37.26%, 47.36% and 59.59% respectively. At present, this profit is lost due to inefficiency.

Profit loss is the potential profit that has been lost due to inefficiency and is enterprise-specific, depending on prices and fixed factor levels. It can be computed for each innovation groups as maximum profit less actual profit. Maximum profit is measured as actual profit divided by profit efficiency estimate, both enterprise-specific. Average profit loss is 109.62 €/str (Table 6). Profit loss is minimized for innovation group 6, increasing in less innovative farmers, rising up to the level of 216.52 €/str. for innovation group 1. This way, the aforementioned substantial scope for improvement (especially for less innovative farmers), acquires a clear, quantifiable measure.

Innovation has a significant (at 1% level) positive contribution in reducing the inefficiency scores, as expected (refer to inefficiency effects model in Table 3). Note well that negative sign in the coefficient of λ_1 is due to the measurement of the effects of innovation variable on inefficiency-not on efficiency-scores. Innovations, adopted by organic olive farmers, can contribute in the increase of technical profit efficiency by allowing them to produce the same quantity of output by using less labour, or less materials. In addition, innovations may increase allocative profit efficiency by making olive farmers able to produce the same quantity of output by choosing a better combination of inputs, one that reduces production cost. The exact effect of each innovation depend on factors, as whether it is labour or materials saving, its type (variable or quasi-fixed input), purchase cost, life-span and the enterprise size. As a result, a decrease in profit efficiency and consequently an increase in profit, can be achieved by adopting one or more innovations, that innovation variable is constructed of. This strong indirect effect of innovation in normalized profit complements the increasing direct effect of innovation variable on it, discussed above.

CONCLUSION

In this study, the contribution of innovations in profit efficiency and profit loss of organic olive farmers was measured. This was achieved by using primary cross section data on organic olive enterprises and applying the restricted frontier profit function. Differences in innovative profile among farmer groups were proxied by an innovation variable. Efficiency differences among innovation groups were also estimated.

It was found that adoption of innovations (both embodied in capital and regarding variable inputs) as well as the value of high-tech capital enhances profitability of the olive enterprise. In addition, the average profit efficiency is 61.15%, considerably increased in more innovative farmers. This, in conjunction with the significant positive contribution of innovation in reducing the inefficiency scores, results in the least profit loss for the most innovative farmers. In contrast, profit loss increases substantially for less innovative farmers. Given the wide distribution of farmers across innovation groups, one can imply that there is major scope for improvement for the average farm.

Agricultural extension services can assist in facilitating diffusion of agricultural innovations and reinforce the most important factors that constitute the innovative farmer. This is a multi-disciplinary work, which need to be carried out through mobilization of agriculturists, economists, engineers etc. and should involve not only innovations embodied in capital, but innovative variable inputs as well.

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