# The contribution of innovations in total factor productivity of organic olive enterprises

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*Abstract* — **This paper measures the contribution of innovations in total factor productivity (TFP) of organic olive farmers. By constructing an innovation variable instead of the use of a time trend, technical change is replaced by technical difference and TFP growth becomes TFP difference. Primary cross section data on organic olive enterprises from a Greek region is used in the application of the restricted frontier profit function. Farmers are classified into groups according to their innovative 'profile'. TFP difference among consecutive innovation groups is decomposed into technical difference and adjustment in innovativeness effects. Furthermore, efficiency differences among innovation groups are estimated. Results indicate that more innovative farmers perform better than less innovative ones regarding TFP and efficiency scores. Adoption of innovations has a positive contribution in the reduction of inefficiency and profit-loss. The rate of technical difference is always positive in the formulation of TFP difference whereas the adjustment in innovativeness effects varies among the innovation groups. Finally, high-tech capital is more or less under-utilized, regardless of the innovation group**.

*Keywords* — **Innovations, total factor productivity, profit efficiency, organic farming, Greece**

## I. 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 firstly, to measure the contribution of innovations in total factor productivity (TFP) of organic olive farmers and secondly, to identify the relative contribution of TFP's components in its formulation. To this end, a new methodology in the measurement of productivity difference is proposed, when cross section data is available. Earlier studies decompose TFP change in several components in a time series or panel data context (for a review on TFP measurement see Nadiri [3], Diewert and Lawrence [4] or Kumbhakar [5]). In addition, TFP difference across countries has been studied using macroeconomic data [6]. The contribution of this study is the measurement of TFP difference among individual groups, using a cross section dataset. The key point is the use of an innovation variable instead of the usual time trend, to proxy technical difference among farmer groups, instead of technical change over time. This is done by applying the restricted frontier profit function. Efficiency is studied apart from the decomposition of TFP difference into its components, as the frontier profit function does not allow incorporation of both, efficiency and capacity utilization in a single decomposition analysis. Furthermore, capital is segregated in high-tech and non high-tech capital, in order to capture differences in the capacity utilization of high-tech capital among farmer groups.

The paper is structured as follows: the following section presents the concept of profit efficiency measurement, introduces the innovation index, innovation groups and innovation variable, explains the measurement of TFP difference and decomposes it into its components. The study area is presented in section 3 and the empirical model is analyzed in section 4. Section 5 provides the results of the study and finally, some policy implications are drawn along with the conclusion.

## II. METHODOLOGY

### A. Profit efficiency measurement

In this paper, 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 [7]. The stochastic profit function is defined as:

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

where $\pi_i$ is normalized profit of farm *i*, defined as gross revenue less variable cost, divided by farm-specific output price; $P_{ij}$ 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; $\xi_i$ is an error term; and $i$ = 1,…,n is the number of farms in the sample.

Following Kmenta [8] (for the production function) and Ali and Flinn [9] (for the profit function), the error term $\xi_i$ is assumed to have a consistent with the frontier concept behaviour:

$$\xi_i = v_i - u_i$$

$v_i$ is the independently and identically distributed $N(0, \sigma_v^2)$ 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 $\sigma_u^2$, where $W_{di}$ is the $d^{th}$ variable explaining inefficiency of farm *i* and $\delta_0$ and $\delta_d$ are parameters to be estimated.

### B. 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; adoption of each one of them adds one point to the index, except for one, weight of which was supposed to be double. Innovation index takes continuous values between 0 and 11 because some innovations are applied not necessarily in the whole olive enterprise, but in 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 [10] classification, whereas those scoring between $5 \cdot 11/6$ 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 that meets Kmenta's [8] qualifications for dummy variables. It will be used as a proxy of technical progress.

Innovation index captures differences among farmers in the adoption of innovations, regardless of the type of those, that is, embodied in capital inputs or not. However, there are 7 out of 10 capital-embodied innovations in organic olive farming. Hence, in such a research study, the segregation of capital into high-tech and non high-tech was deemed necessary in order to draw possible meaningful inferences such as different high-tech capacity utilization among innovation groups.

### C. From TFP change to TFP difference measurement

There is considerable number of articles in international literature related to the decomposition of TFP growth, measuring the difference on TFP levels over time, in a time series or panel data context. Technical progress is proxied by a time trend or the general index of Baltagi and Griffin [11] and is measured as technical change from one period to the next. The remaining TFP components follow a similar time-based measurement and explanation as well. In this article, TFP difference among innovation groups is measured and decomposed in several components on a cross section basis. Technical progress is proxied by the innovation variable instead of a time trend. The remaining TFP components follow a cross section measurement and explanation, resulting by comparing different innovation groups.

Some benefits of the proposed methodology are:

- The cross section nature of technical progress is integrated in the analysis of TFP allowing for more comprehensive and multidimensional results.

- The econometric problem of endogeneity between innovation and productivity (see Crépon et al. [12]) is solved because technical difference, resulting by different innovative profile of farmers, gives a straightforward explanation of TFP difference, which is from innovation to productivity.
- It allows further analysis of already published studies, relying on primary data on innovations.

*D. Decomposition of TFP difference*

Since there is no way to incorporate both efficiency and capacity utilization as components of TFP difference by using a frontier profit function framework (no such decomposition is available in international literature), efficiency will be studied aside from TFP decomposition. Let $\pi = \pi(p, w; z, I)$ (1) be a well-defined restricted profit function, where $\pi$ 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. We follow the methodology of Karagiannis and Mergos [13] in decomposing TFP difference in a similar path of their TFP growth decomposition. By applying an input-based measure of technical difference, the following expression is finally obtained (see appendix for the derivation of the expression in detail):

$$\frac{\Delta TFP}{TFP} = \pi_1 + \left(\rho_Z^{-1} - 1\right)\frac{\Delta Q}{Q} + \sum_{k=1}^{h}\left(\frac{r_k - v_k}{TC} z_k\right)\left[\frac{\Delta X'}{X'} - \left(\frac{\Delta z_k}{z_k}\right)\right].$$

The components of TFP difference are defined according to the innovation variable context. They are related to the concept of TFP difference among innovation groups in a specific moment of time, instead of the usual TFP growth over time pattern, developed in the above and other articles. The first component is the rate of technical difference among innovation groups, being positive when an increase on the innovation group comes with an advanced level of technology usage. This corresponds to the progressive technological change in the TFP growth framework. We expect this figure to follow an increasing path towards more innovative groups since there is no element of the innovation index that could be characterized by its regressive technological effects.

The second term is returns to scale and a zero value indicates constant returns to scale for farmers of the innovation group in question. If returns to scale are increased for the next innovation group, the more innovative farmers of that group are increasing output more than farmers of the last innovation group, for the same proportional increase on inputs. Returns to scale take the zero value when there is a single output and profit is normalized with the price of it ($p$), as well. This may be the case when a frontier profit function is estimated and normalization is necessary for the joint study of profits and input prices of all farms to be feasible. This case holds for the present study (see below).

The last term may be called ‘adjustment in innovativeness’, which is the adjusted sum of capacity utilization of the quasi-fixed inputs. Adjustment in innovativeness refers to the degree that an innovative farmer has adjusted the level of quasi-fixed inputs in order to meet the needs of his enterprise ‘innovative profile’. Capacity utilization of a quasi-fixed input is zero when its shadow price does not diverge from the rental price, which signifies optimal use on the level of this quasi-fixed input. A quasi-fixed input is over- (under-) utilized if its shadow price is greater (lower) that the rental price.

In the time context, apart from being a TFP component, technical change has been measured by the first derivative of the restricted translog profit function with regard to time variable $\left[\frac{\partial \ln \pi(p, w, z, t)}{\partial t}\right]$. Several authors use different term to describe it, such as ‘dual rate of TFP’ [14], ‘rate of profit augmentation’ ([13]; refer to that article for the relationship between the primal measures of technical change and the rate of profit augmentation, as well), or ‘a measure of technical progress’ [15]. In the innovation variable context, this corresponds to $\frac{\partial \ln \pi(w, z, I)}{\partial I}$ and expresses reduced input requirements that an innovative farmer faces in order to produce the same quantity of output, as a less innovative one. These reduced input requirements are reflected upon reduced cost, being the innovation effect. This definition is consistent with the input-oriented approach of technical progress, followed in this article and describes the ‘rate of cost diminution’ by adoption of innovations. This term is often used in cost function approaches (see Chambers [16], Berndt [17], Antle and Capalbo [18]). Nevertheless, its output-oriented proportionate, namely ‘rate of revenue growth’ may also hold for the profit function approach. Thus, we believe that the term ‘rate of profit augmentation’ describes best the attribute of combining both the cost and revenue sides of the profit function, being adopted in the rest of this article. Its difference from the rate of technical difference is that the latter describes the contribution of technical progress in the formulation of TFP difference between innovative and less innovative farmers, whereas rate of profit augmentation is a relative measure of profits, that the adoption of innovations enable innovative farmers to have increased, compared to less innovative farmers.

## III. 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 [19]. They are: Xalkidiki, Kavala, Thessaloniki and Serres prefectures. Into 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 in 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 in 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 in the enterprises of the farm, according to the contribution of the enterprises in the configuration of total farm revenue.

## IV. The empirical model

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 [20] in order to increase the efficiency of estimation. Dropping the property-specific subscripts to avoid confusion, the translog restricted frontier profit function becomes:

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

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

$\pi$ = variable profit per str. (gross revenue less variable cost) normalized with respect to 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 7 capital-embodied innovations

$z_N$ = 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.

$I$ = 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

$\alpha_0$, $\beta_i$, $\gamma_k$, $\delta_1$, $\delta_2$, $\beta_{il}$, $\gamma_{km}$, $\zeta_{ik}$, $\eta_i$, $\theta_k$, $\varepsilon_r$, $\lambda_0$, $\lambda_1$ are parameters 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, it 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.

## V. Results

The translog restricted frontier profit function is estimated using the maximum-likelihood method with the computer program FRONTIER 4.1 [21]. 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. The monotonicity condition holds in the sample mean for both input prices, that is, input profit shares, obtained by Hotelling's Lemma, are negative. In addition, 3 out of 4 quasi-fixed input shares are positive, as they should be. 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 $30^{th}$ ($50^{th}$) 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 $\gamma$ is bounded between 0 and 1. Estimated value of $\gamma$ (0.999) is very close to 1, indicating that inefficiency effects are affecting much more total variance $\sigma^2$ than random noise, in the estimated restricted profit function. However, this can be subjected to statistical verification, using the Likelihood Ratio test statistic. The likelihood-ratio (LR) test statistic conducted in order to test appropriateness of the adopted specification against others. Alternative hypotheses pertaining to: 1) $\gamma$=0, 2) $\lambda_0 = \lambda_1 = 0$, 3) different definitions of capital and 4) Cobb-Douglas functional form and were all rejected at the 1% level of significance.

Results suggest that adoption of innovations (both capital-embodied and regarding variable inputs) as well as the value of high-tech capital enhances profitability of the olive enterprise. The distribution of profit efficiency estimates for the six innovation groups is shown in table 1 and figure 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.

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 (figure 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 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 2). 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. 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.

Table 1. Frequency distribution of enterprise-specific profit efficiency estimates*

| Efficiency estimate (%) | Innovation group 1 | | | Innovation group 2 | | | Innovation group 3 | | | Innovation group 4 | | | Innovation group 5 | | | Innovation group 6 | | | total sample | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 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 | 5 | 16.67 | 100 | 10 | 27.78 | 100 | 7 | 25.00 | 100 | 14 | 53.85 | 100 | 14 | 60.87 | 100 | 54 | 32.65 | 100 |
| 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

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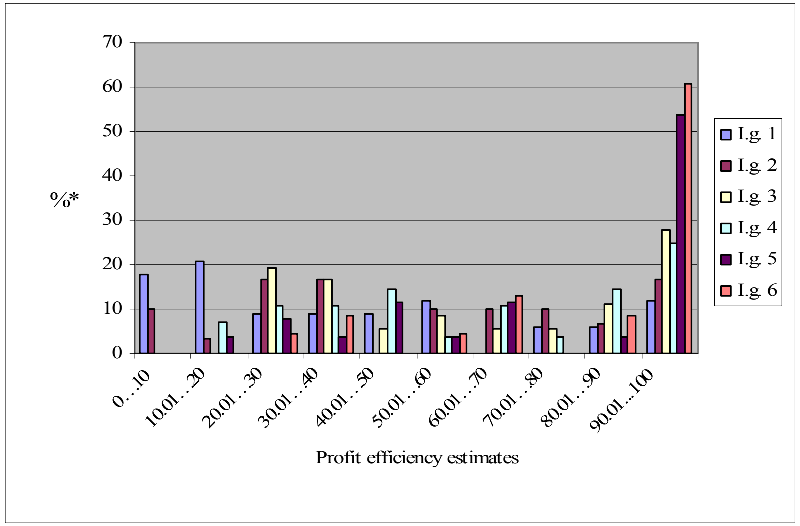


Figure 1. Histogram of profit efficiency estimates for the six innovation groups

* Percentage of the frequency of profit efficiency estimates within an innovation group

Table 2. 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 |

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.

Let us now turn to the measurement of technical progress and TFP difference. The rate of profit augmentation is computed by the restricted profit function as follows: $\frac{\partial \ln \pi}{\partial I} = \delta_1 + \delta_2 I + \sum_{i=1}^{2} \eta_i \ln w_i + \sum_{k=1}^{4} \theta_k \ln z_k$. The results are presented in table 3. The average rate of profit augmentation between consecutive innovation groups is 8.46%. That is, farmers of a certain innovation group are able to produce the same output quantity as farmers of the last group, with reduced cost by 8.46% on average (input oriented approach). Rate of profit augmentation is considerably increased in the mid-innovative farmers (groups 3 and 4), suggesting that less innovative farmers (groups 1 or 2) can experience a substantial increase in their profits by adopting a few more innovations in question.

All innovation groups underutilize their high-tech capital and this is becoming more intense in innovative farmers (see table 3). In detail, innovation groups 1 and 2 slightly diverge from the optimum use of their high-tech capital. The level of the high-tech capital almost fully corresponds to the level of the other inputs. Innovation groups 3 and 5 are underutilizing a bit more their high-tech capital, whereas the level of high-tech capital of innovation groups 4 and 6 depart from optimum capacity utilization. However, taking into consideration that adoption of innovations (both capital-embodied and regarding variable inputs) as well as the value of high-tech capital enhances profitability, one could infer that it is not the adoption of innovations alone, that contributes in this increasing departure from the optimum capacity utilization, but the fact of not being followed by intensification on the whole olive enterprise. That is, given that the level of high-tech capital and mean enterprise size is increased in more innovative farmers and the positive effect of high-tech capital in normalized profit, intensification should refer to the quantity of labour and materials used. Enterprises of innovation groups 5 and 6 are more intensified with regard to the land and this is reflected on the diminished degree of land under-utilization (table 3). Under-utilization of quasi-fixed inputs is the case for non high-tech capital and tree capital as well.

Table 3. Rate of profit augmentation and capacity utilization per innovation group

| | Rate of profit augmentation (%) | Capacity utilization | | | |
|---|---|---|---|---|---|
| | | High-tech capital | Non high-tech capital | Land | Tree capital |
| I.g. 1 | - | 0.022 | 0.087 | 0.173 | 0.215 |
| I.g. 2 | 5.28 | 0.020 | 0.149 | 0.176 | 0.236 |
| I.g. 3 | 15.45 | 0.046 | 0.153 | 0.207 | 0.188 |
| I.g. 4 | 11.92 | 0.138 | 0.107 | 0.168 | 0.252 |
| I.g. 5 | 0.33 | 0.049 | 0.256 | 0.042 | 0.421 |
| I.g. 6 | 9.33 | 0.138 | 0.194 | 0.059 | 0.441 |
| Total sample | 8.46* | 0.069 | 0.158 | 0.138 | 0.292 |

* Average

Table 4 summarizes TFP difference and its components among the six innovation groups comparing two consecutive groups and figure 2 depicts a cumulative index of TFP difference with regard to the first innovation group. TFP is increased in more innovative groups apart from group 2 that exhibits the lowest TFP. The average rate of TFP difference is 2.438%. Technical difference has always a positive contribution on TFP difference. Increased TFP for innovation groups 3 and 4 is due to the technical difference effect, whereas the adjustment in innovativeness effect pulls downwards the cumulative index of TFP difference. What is most, the light effect of technical difference, combined with the extreme low of adjustment effect, yields negative TFP difference rate for innovation group 2. The meaning of those is that adoption of innovations for groups 2-4 takes place without optimum adjustment of the four types

Table 4. Decomposition of TFP difference (%)

| | Technical difference | Adjustment in innovativeness | TFP difference |
|---|---|---|---|
| I.g. 2 | 0.243 | -4.707 | -2.232 |
| I.g. 3 | 3.881 | 4.486 | 4.184 |
| I.g. 4 | 4.520 | -2.390 | 1.065 |
| I.g. 5 | 0.302 | 9.291 | 4.797 |
| I.g. 6 | 10.656 | -1.902 | 4.377 |
| Average | 3.921 | 0.956 | 2.438 |

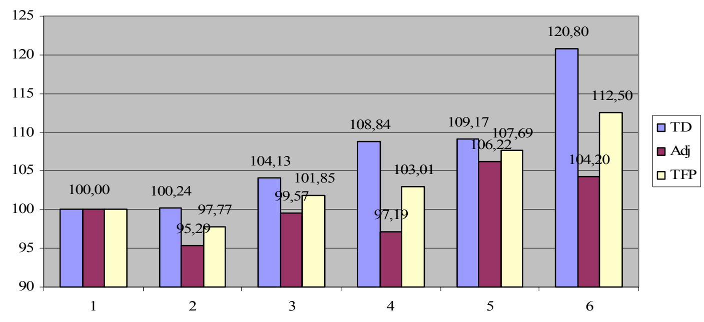


Figure 2. Cumulative index of TFP difference and its components between the least innovative farmers (group 1) and each one of the rest innovation groups

of capital in the innovative 'profile' of the organic olive enterprise. Innovative farmers probably face difficulties in fitting innovations with the structure of their enterprise, taking full advantage of the combination: innovations in use – quasi-fixed inputs employed in the production process. This situation is reversed for innovation groups 5 and 6. Innovative farmers of those groups perform better enough in the above profitable combination which, combined with the steady increase of technical difference rate, results in high rates of TFP difference. Hence, when adopted innovations are integrated in the structure of the organic olive enterprise and quasi-fixed inputs are adjusted towards the innovative 'profile' of the enterprise, its TFP follows an increasing trend.

## VI. Conclusion – Policy Implications

Adoption of innovations (both capital-embodied 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 with innovation to have a significant positive contribution in reducing the inefficiency scores. These results in the least profit loss for the most innovative farmers. In contrast, profit loss increases substantially in less innovative farmers. These, in conjunction with the distribution of farmers across innovation groups 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.

The rate of profit augmentation is considerably increased in the mid-innovative farmers, suggesting that less innovative farmers can experience a substantial increase in their profits by adopting a few more innovations. However, all innovation groups underutilize their high-tech capital and this is becoming more intense in innovative farmers. This is due to the adoption of innovations merely alone, without an intensification on the whole olive enterprise, regarding the quantity of labour and materials used. Hence, adoption of innovations should regard variable innovative inputs rather than high-tech capital, if innovative behavior is not accompanied by an increase in the use of labour and materials. At that point, a question arises as to the level of labour and material intensification that organic farming of olive tree allows. Is there room for improvement towards labour and material intensification or adoption of innovations should be oriented towards innovative variable inputs? In addition, the regulatory environment for organic farming may be too restrictive, orienting farmers towards investments in high-tech capital, because there is no other choice for intensifying their enterprise. Further research on the correlation of each type of innovation with its own effect on profitability and productivity could help dealing with this issue. The effect of regulatory tightness of European Union's policy for organic farming in the formulation of different innovative profiles is an interesting research field too.

Finally, TFP is increased in more innovative groups. The average rate of TFP difference is 2.438%. The contribution of technical difference is always positive. Mid-innovative farmers face difficulties in fitting innovations with the optimum level of quasi-fixed inputs, whereas innovative farmers perform better enough in the above profitable combination and the overall TFP score. These suggest that the adjustment of the levels of the quasi-fixed inputs towards the innovative 'profile' of organic olive enterprise results in the increase of TFP. Thus, the task of agricultural extension services must be multi-objective, apart from reinforcing the most important factors that can spur adoption of innovations by farmers. Farmers must be taught how to incorporate adopted innovations in their enterprise, making the most out of them, adjusting the levels of other inputs in their own innovative profile. This is a multi-disciplinary work, which must be carried out through mobilization of agriculturists, economists, engineers etc.

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## Appendix

Based on Karagiannis and Mergos (2000) returns to scale can be expressed in a dual form for the case of innovation variable as:

$$\rho_Z = \frac{-\sum_{i=1}^{n} S_i + \sum_{k=1}^{h} M_k}{\sum_{j=1}^{m} R_j} = \frac{C^*}{TR} = 1 - \left( \sum_{j=1}^{m} \frac{\partial \ln \pi}{\partial \ln p_j} \right)^{-1} + \frac{\sum_{k=1}^{h} \frac{\partial \ln \pi}{\partial \ln z_k}}{\sum_{j=1}^{m} \frac{\partial \ln \pi}{\partial \ln p_j}} \quad (2),$$

where $x$ and $q$ are input and output quantities, $S_i = \frac{w_i x_i}{\pi}, R_j = \frac{p_j q_j}{\pi}$ , $M_k = \frac{\partial \ln \pi}{\partial \ln z_k}$, $TR$ is the revenue, $C^* = \sum_{i=1}^{n} w_i x_i + \sum_{k=1}^{h} \left( \frac{\partial \pi}{\partial z_k} \right) z_k$ is total shadow cost and $\frac{\partial \pi}{\partial z_k} = v_k \left( p, w; z, I \right)$ is the shadow value of the $k^{th}$ quasi-fixed input. Let us now define the rate of technical difference, as:

$$\pi_I = \left( \frac{\partial \ln \pi}{\partial I} \right) \left( \frac{\pi}{TC} \right) \quad (3).$$

Derivation of TFP decomposition follows. Taking the total differential of (1) with respect to I yields

$$\frac{d\pi}{dI} = \sum_{j=1}^{m} \left( \frac{\partial \pi}{\partial p_j} \right) \left( \frac{dp_j}{dI} \right) + \sum_{i=1}^{n} \left( \frac{\partial \pi}{\partial w_i} \right) \left( \frac{dw_i}{dI} \right) + \sum_{i=1}^{n} \left( \frac{\partial \pi}{\partial z_k} \right) \left( \frac{dz_k}{dI} \right) + \frac{\partial \pi}{\partial I} \quad (4).$$

Applying Hotelling's Lemma in (1) gives $\frac{w_i x_i}{\pi} = -\frac{\partial \ln \pi}{\partial \ln w_i}$ and $\frac{py}{\pi} = \frac{\partial \ln \pi}{\partial \ln p}$ (5). Dividing all terms in (4) by π, taking into consideration (5), produces:

$$\frac{d \ln \pi}{dI} = \sum_{j=1}^{m} \left( \frac{p_j q_j}{\pi} \right) \left( \frac{\Delta p_j}{p_j} \right) - \sum_{i=1}^{n} \left( \frac{w_i x_i}{\pi} \right) \left( \frac{\Delta w_i}{w_i} \right) + \sum_{k=1}^{h} M_k \left( \frac{\Delta z_k}{z_k} \right) + \frac{\partial \ln \pi}{\partial I} \quad (6).$$

Considering that $\pi = \sum_{j=1}^{m} p_j q_j - \sum_{i=1}^{n} w_i x_i$ and taking its total differential with respect to $I$, the following expression is obtained

$$\frac{d\ln\pi}{dI}=\sum_{j=1}^{m}\left(\frac{p_j q_j}{\pi}\right)\left(\frac{\Delta p_j}{p_j}\right)+\sum_{j=1}^{m}\left(\frac{p_j q_j}{\pi}\right)\left(\frac{\Delta q_j}{q_j}\right)-\sum_{i=1}^{n}\left(\frac{w_i x_i}{\pi}\right)\left(\frac{\Delta w_i}{w_i}\right)-\sum_{i=1}^{n}\left(\frac{w_i x_i}{\pi}\right)\left(\frac{\Delta x_i}{x_i}\right) \quad (7).$$

Equating (6) and (7) results in

$$\frac{d\ln\pi}{dI}=\sum_{j=1}^{m}\left(\frac{p_j q_j}{\pi}\right)\left(\frac{\Delta q_j}{q_j}\right)-\sum_{i=1}^{n}\left(\frac{w_i x_i}{\pi}\right)\left(\frac{\Delta x_i}{x_i}\right)-\sum_{k=1}^{h}M_k\left(\frac{\Delta z_k}{z_k}\right) \quad (8).$$

Let (8) be divided by $-\sum_{i=1}^{n}S_i+\sum_{k=1}^{h}M_k=C^*/\pi$ to get:

$$\left(\frac{\partial\ln\pi}{\partial I}\right)\left(\frac{\pi}{C^*}\right)=\sum_{j=1}^{m}\left(\frac{p_j q_j}{C^*}\right)\left(\frac{\Delta q_j}{q_j}\right)-\sum_{i=1}^{n}\left(\frac{w_i x_i}{C^*}\right)\left(\frac{\Delta x_i}{x_i}\right)-\sum_{k=1}^{h}\left(\frac{v_k z_k}{C^*}\right)\left(\frac{\Delta z_k}{z_k}\right)$$

which can be rewritten as:

$$\frac{\Delta Q}{Q}=\sum_{j=1}^{m}\left(\frac{p_j q_j}{TR}\right)\left(\frac{\Delta q_j}{q_j}\right)=\pi_1+\left(\rho_Z^{-1}-1\right)\frac{\Delta Q}{Q}+\sum_{i=1}^{n}\left(\frac{w_i x_i}{C^*}\right)\left(\frac{\Delta x_i}{x_i}\right)-\sum_{k=1}^{h}\left(\frac{v_k z_k}{C^*}\right)\left(\frac{\Delta z_k}{z_k}\right) \quad (9)$$

if 2 and 3 are taken into consideration. On the left side of this relationship, the difference of aggregate output among innovation groups is expressed. On the right, the contribution of technical difference ($\pi_I$), returns to scale $\left[\left(\rho_Z^{-1}-1\right)\frac{\Delta Q}{Q}\right]$ and difference in the level of input use in the difference of aggregate output is shown. The difference in the level of input use exists separately for variable $\left[\sum_{i=1}^{n}\left(\frac{w_i x_i}{C^*}\right)\left(\frac{\Delta x_i}{x_i}\right)\right]$ and quasi-fixed inputs $\left[\sum_{k=1}^{h}\left(\frac{v_k z_k}{C^*}\right)\left(\frac{\Delta z_k}{z_k}\right)\right]$.

Now suppose $TC'=\sum_{i=1}^{n}w_i x_i+\sum_{k=1}^{h}r_k z_k$, where r is the rental price of quasi-fixed inputs (defined as the value of quasi-fixed input minus total depreciation).

In addition, $\frac{\Delta z_k}{z_k}=\frac{d\ln z_k}{dI}$ and $TC'-C^*=\sum_{k=1}^{h}(r_k-v_k)z_k$.

In the context of TFP difference, the Divisia index of TFP growth becomes:

$$\frac{\Delta TFP}{TFP}=\frac{\Delta Q}{Q}-\frac{\Delta X'}{X'}=\sum_{j=1}^{m}\left(\frac{p_j q_j}{TR}\right)\left(\frac{\Delta q_j}{q_j}\right)-\sum_{i=1}^{n}\left(\frac{w_i x_i}{TC'}\right)\left(\frac{\Delta x_i}{x_i}\right)-\sum_{k=1}^{h}\left(\frac{r_k z_k}{TC'}\right)\left(\frac{\Delta z_k}{z_k}\right)$$

and by substituting (9):

$$\frac{\Delta TFP}{TFP}=\pi_1+\left(\rho_Z^{-1}-1\right)\frac{\Delta Q}{Q}+\sum_{k=1}^{h}\left(\frac{r_k-v_k}{TC}z_k\right)\left[\frac{\Delta X'}{X'}-\left(\frac{\Delta z_k}{z_k}\right)\right].$$

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