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# Decomposition of Output Growth in the Tunisian Olive-Growing Sector: A Frontier Production Function Approach

**B. Dhehibi[•], L. Lachaal, B. Karray, and A. Chebil**

**Abstract -** The aim of this paper is to investigate the relative contribution of technical efficiency, technological change and increased input use to output growth in the Tunisian olive growing sector using a stochastic frontier *translog* production function applied to panel data for the period 1995-1997. Results indicate that technical efficiency of production in the sample of farms investigated ranges from a minimum of 24.8% to a maximum of 84.6% with an average technical efficiency estimate of 48.5%. This suggests that olive producers in the sample may increase their production by as much as 51.5% through a more efficient use of production inputs. Further, production of olives in the sample of farms investigated is characterized by decreasing returns to scale; 0.8 on average. Finally, investigation of the sources of production growth reveals that the contribution of conventional inputs (labour, in particular) and technical change constitute the main sources of growth in the sector.

[•] Comments are welcome; please send any communication directly to the authors.

# Decomposition of Output Growth in the Tunisian Olive-Growing Sector: A Frontier Production Function Approach

## 1. Introduction

The olive oil sector is an important ingredient in the Tunisian economy for a number of reasons. First, in terms of employment and income generation, this sector produced, in the year 2000, 1,125 million tons of olive, which amounted to 10% of the value of agricultural production and contributed about 1.2% to the growth of domestic product. Second, olive oil production, which grew at an annual rate of 6.6% during the period 1990-2000, is an important source of foreign exchange earnings and accounts for 46% of agricultural exports. Thus, given the importance of this sector in the national economy, policy recommendation in the last two decades has been to make this sector more competitive by furthering production growth and increasing exports.

Further, Tunisia's implementation of the free trade agreement with the EU (signed in 1995) has contributed to the reduction of tariffs and other trade barriers on a wide range of goods and services traded with the EU. Thus, the olive growing sector is coming under increasing international competition, which calls for a major concern because only efficient farms are likely to stand the competitive pressure in the ever changing world economy. To this end, knowledge of the relative contribution of factor productivity and input use to output growth and improvements in technical efficiency is crucial to providing a comprehensive view of the state of the olive producing sector and help farm managers and policy makers draw appropriate policy measures.

Taking into account the above, this paper investigates the relative contribution of technical efficiency, technological change and increased input use to output growth in the olive oil sector using a stochastic frontier production function approach applied to panel data. A flexible *translog* functional form is used to represent the underlying production technology and maximum likelihood procedure is implemented to estimate a single time trend model. This study, which addresses the main issues that have bearings on technical efficiency in the olive growing sector in Tunisia is important for, to the authors' knowledge, few studies have addressed theses issues (Lachaal et *al.*, 2005).

The remainder of this paper is organized as follows. Section 2 reviews the literature. In section 3, we present the olive oil sector in Tunisia. In section 4, we describe statistical data paying special attention to the region of study, the questionnaire and the sampled olive growing farms. In section 5, we present the theoretical background of the production frontier model. Section 6 presents the empirical results and discussions and section 7 concludes with some remarks on policy implications.

## 2. Literature review

The crucial role of efficiency gains in increasing agricultural output has been widely recognized in the research and policy arenas. It is not surprising; therefore, that considerable effort has been devoted to the measurement and analysis of productive efficiency, which has been the subject of a myriad of theoretical and empirical studies for several decades since Farrell's (1957) seminal work. Forsund, Lovell and Schmidt (1980) provide in an earlier survey an overview of various approaches to frontier analysis and efficiency measurement. More recent surveys of these techniques include Bauer (1990), Battese (1992) and Greene (1993).

Equally important in the analysis of production efficiency is to go beyond the measurement of performance and examine exogenous influences on efficiency. To this end, exogenous variables characterizing the environment in which production occurs have been incorporated into efficiency measurement models in a variety of ways. Early contributions to the literature on this issue include Pitt and Lee (1981) and Kalirajan (1981). These applications adopted a two-step formulation. More recently, approaches to the incorporation of exogenous influences have been refined and significant improvements in modelling technical inefficiency effects in stochastic frontier models opened new directions for empirical analysis (Kumbhakar and Lovell, 2000).

Traditionally, output growth has been attributed to three effects, namely, input growth, technical change and improvements in technical efficiency (Fan, 1991; Ahmad and Bravo-Ureta, 1995; Wu, 1995; Kalirajan *et al*., 1996 and, Kalirajan and Shand, 1997). These applications; however assumed implicitly that technical change and changes in technical efficiency are the only components of total factor productivity (TFP) changes. Nevertheless, returns to scale and allocative efficiency may also be significant sources of TFP growth and consequently, of output expansion.

Indeed, there is empirical evidence that scale economies stimulate output growth even in the absence of technical change and improvements in technical efficiency as long as input use increases. Analogously, diseconomies of scale could slowdown output growth under similar circumstances, which is more likely to be the case for agriculture.

On the other hand, output gains may also be obtained by improving allocative efficiency. In highly protected sector, such as agriculture, allocative inefficiency tends to be an important source of TFP slowdown (Fulginiti and Perrin, 1993; Kalaitzandonakis, 1994). Nevertheless, in the presence of price support schemes, the improvement of allocative efficiency provides an additional incentive for output increases.

## 3. The olive oil sector in Tunisia: An overview

The olive oil sector, which marked the history of Tunisia's rural population, covers more than 1.6 million hectares, representing 79 percent of total fruit trees planted surface and close to 35 percent of arable lands. This sector constitutes also the principal activity of a diversified range of farming systems, representing nearly 57 percent of total agricultural farm labour.

The sector also has an important industrial base with nearly 1,600 equipped oil mills having a total olive triturating capacity of 30 thousand tons per day; 10 factories of sulphurous oil extraction with a theoretical capacity of about 2 thousand tons per day; 11 units of refining edible oil with a total capacity of 900 tons per day; 24 conditioning units equipped with a capacity of 15 thousand tons and several soap factories. Since 1994, marketing of olive oil has been administrated by the *Office National de l'Huile* (ONH), a state owned company and by more than 90 private exporters.

The olive-growing sector in Tunisia accounts for about 16% of the world olive-growing area (second after Spain), corresponding to about 6% of the total number of olive oil trees in the world (seventh after Spain, Italy, Greece, Turkey, Morocco and Syria). It contributes, on average, 5% to the world olive oil production ($4^{th}$ position after Spain, Italy and Greece) and 11.4% to world exports ($4^{th}$ position after Italy, Spain and Greece) with 125 thousand tons per year. The degree of integration of Tunisia to world olive oil market measured by the percentage of exported oil quantities to produced ones is 97.6 %. But, at the world market level, Tunisia's share of total olive oil market is only 9.8%. This share becomes 12.5% on the European market, 16% on the Italian market and 22.7% on the Spanish market. These last two countries represent the principal destinations of the Tunisian olive oil exports.

In addition to this undeniable economic role, the olive oil sector plays a crucial social and environmental role by providing more than 30 million working days per year, which corresponds to 20% of agricultural employment and contributes to the reduction of rural migration and exodus to urban areas.

## 4. Sources and data analysis

### 4.1. Region of study

The region of Sfax is the first producer and exporter of olive oil in the country. According to the statistics of the Ministry of Agriculture, this region accounts 34% of the triturating capacity and contributes by as much as 37%, 68% in national olive oil production and exports, respectively.

Sfax is located in the Centre East of the country and it is limited by the governorate of Mahdia to the North, Kairouan, Sidi Bouzid and Gafsa to the West, Gabès to the South and the Mediterranean Sea to the East. Adapted to the edaphic and climatic conditions of this region, the olive oil tree has been propagated, through several generations, on the totality of the arable lands to cover, nowadays, more than 312 thousand hectares accounting for 44% of the total agricultural surface and 19% of the national olive-growing surface. Plantations of olive-trees (6.13 million trees) are made up of 100% by the *chemlali variety*, 83% of them are exclusively olive trees with an average density of 20 trees/ha. About 16 % of olive plantations in the region of Sfax are less than 20 years old, 49 % ranging between 20 and 70 years and 35 % are more than 70 years old.

### 4.2. Survey of olive growing farms

A panel data of 178 Tunisian olive producing farms are collected from surveys conducted in 12 delegations of the governorate of Sfax. Olive-growing farms were selected from the sample used by the Tunisian Ministry of Agriculture in order to investigate the structure of agricultural farms carried out in 1995, 1996 and 1997 in the Sfax region (Karray, 2002). This selection was carried out in collaboration with the statistical and agricultural development office and the territorial information units of the Agricultural Regional Office of Sfax region, taking into account the statistical representation and cultivated areas.

The selected sample comprises 125 farms with a size lower than 20 ha (representing 70.2%), 34 farms with a size ranging between 20 and 100 ha (19%) and 19 farms with a size larger than 100 ha (10.7%). It represents a total agricultural surface of about 7,075 ha comprising 5,338 ha planted exclusively with olive trees, 589 ha of olive trees in intercalate, 613 ha of various fruit trees, 77 ha of horticulture crops and 98.7 ha in intercalate with olive trees, 40.5 ha of cereals and 387.8 ha of fallow land. Farmers in the sample account also for 1,842 ovine heads, 185 bovine heads and 166 goat heads.

The density of plantation in the sample is about 18 trees/ha on average. The production of olives during 1994/95, 1995/96 and 1996/97 seasons was estimated at 3,776.27 metric tons on average which corresponds to about 35 kg/tree or 637 kg/ha.

### 4.3. The questionnaire and the sample

The questionnaire consists of eleven sections: the first is related to farmer's socio-economic characteristics. This comprise age, education level, agricultural training, experience in olive trees farming, etc. The second section is related to the history of the farm. The third section accounts for the structure of land (area, number of farms, olive varieties, age and density of plantation, etc.). In the fourth section, we focus on production factors, namely labour (permanent, seasonal, family labor and its allocation between farm operations), farming operations, material and buildings, and irrigation operations. The inversion question is treated in the fifth section paying special attention to the olive oil sector in terms of nature of investment (material, land, others). Information in section 6 focuses on credit and loans in terms of amounts and allocations. The intermediate consumption data are collected in section seven. Total production data, production by speculation and costs are treated in section eight. The last three sections are related with the upstream and downstream of theses sector and farmers own perceptions about the olive oil sector. Results of the questionnaire showed that:

- Average age of respondents is 56 years, ranging from 23 to 94.
- Average land holding is 38.59 ha, ranging from 0.5 to 597 ha.

- 9.5% of the sample farmers are illiterate, 38.7 completed primary education; whereas 51.8% accumulated at least 6 years of schooling.
- In terms of land tenure, 86.5% of sampled farmers inherited their farms and 13.5% purchased theirs.
- 93.3% of farmers never followed a training program on conducting olive plantations and improved pruning techniques.
- Almost half of sampled farmers (45.5%) use pruning operations.
- Only 27% of farmers resort to irrigation water use and 30.9% to fertilization operations.
- A high percentage of family labor use with respect to total labour (72.9%).
- In terms of machinery, only 30.9% of sampled farmers have tractors. The other 69.1% resort to hiring.
- Only 8.9% of sampled farmers in the period 1989-1994 have received credits.

## 5. Methodological Framework

### 5.1. Decomposition of total production growth: Theoretical framework

The input-oriented measure of productive efficiency may be defined as:

$$E(y,w,x;t) = C(y,w;t)/C \qquad (1)$$

Where $0 \prec E(y,w,x;t) \leq 1$, $C(y,w;t)$ is a well-defined cost frontier function, $C$ is the observed total cost, $y$ is a vector of output quantities, $w$ is a vector of input prices, and $t$ is a time index that serves as a proxy for technical change.

Using Farrell's decomposition of efficiency,

$$E(y,w,x;t) = T(y,w;t).A(y,w,x;t)$$

Where $T(y,x;t)$ and $A(y,w,x;t)$ are respectively the input-oriented measures of technical and allocative efficiency. By definition, both $T(y,x;t)$ and $A(y,w,x;t)$ lie within the (0, 1] interval, are independent of factor prices scaling and have an analogous cost interpretation.

By taking the logarithm of each side of $E(y,w,x;t) = C(y,w;t)/C$ and totally differentiating it with respect to $t$ yields:

$$\dot{E}(y,w,x;t) = \varepsilon^{Cy}(y,w;t)\,\dot{y} + \sum_{j=1}^{m} s_j(y,w;t)\,\dot{w}_j + C^t(y,w;t) - \dot{C} \qquad (2)$$

Where a dot over a variable or function indicates its time rate of change, $\varepsilon^{Cy}(y,w;t) = \partial Ln\,C(y,w;t)/\partial Ln\,y$, $s_j(y,w;t) = \partial Ln\,C(y,w;t)/\partial Ln\,w_j$, and $-C^t(y,w;t) = \partial Ln\,C(y,w;t)/\partial t$ is the rate of cost diminution.

Alternatively, by taking the logarithm of $C = w' x$, and totally differentiating it with respect to *t*, yields:

$$\dot{C} = \sum_{j=1}^{m} s_j \dot{x}_j + \sum_{j=1}^{m} s_j \dot{w}_j \tag{3}$$

Substituting (3) into (2) results in:

$$\dot{E}(y,w,x;t) = \varepsilon^{Cy}(y,w;t)\,\dot{y} + \sum_{j=1}^{m} s_j(y,w;t)\,\dot{w}_j + C^t(y,w;t) - \sum_{j=1}^{m} s_j \dot{x}_j - \sum_{j=1}^{m} s_j \dot{w}_j \tag{4}$$

Then, using the conventional *Divisia index* measure of TFP changes, i.e.,

$$\dot{TFP} = \dot{y} - \sum_{j=1}^{k} s_j \dot{x}_j = \dot{y} - \sum_{j=1}^{k} s_j \dot{x}_j$$

The time rate of change of $E(y,w,x;t) = T(y,x;t).A(y,w,x;t)$, i.e.,

$$\dot{E}(y,w,x;t) = \dot{T}(y,w;t) + \dot{A}(y,w,x;t)$$

(4) May be rewritten as:

$$\dot{y} = \sum_{j=1}^{m} s_j \dot{x}_j + \left[1 - \varepsilon^{Cy}(y,w;t)\right]\dot{y} - C^t(y,w;t) + \dot{T}(y,x;t) + \dot{A}(y,w,x;t) + \sum_{j=1}^{m}\left[s_j - s_j(y,w;t)\right]\dot{w}_j \tag{5}$$

The first term in (5) captures the contribution of aggregate input growth on output changes over time (size effect). The more essential an input is in the production process, the higher is its contribution to the size effect. The second term measures the relative contribution of scale economies to output growth (scale effect). This term vanishes under constant returns to scale as $\varepsilon^{Cy}(y,w;t) = 1$, while it is positive (negative) under increasing (decreasing) returns to scale, as long as aggregate output increases, and *vice versa*. The third term refers to the dual rate of technical change (cost diminution), which is positive (negative) under progressive (regressive) technical change. The fourth and the fifth terms in (5) are positive (negative) as technical and allocative efficiency increase (decrease) over time. The last term in (5) is the price adjustment effect. The existence of this term indicates that the aggregate measure of inputs is biased in the presence of allocative inefficiency. Under allocative efficiency, the price adjustment effect is equal to zero. Otherwise, its magnitude is inversely related to the degree of allocative inefficiency. The price adjustment effect is also equal to zero when input prices change at the same rate.

**Specific framework: the Tunisian olive oil growing farms production growth**

From an empirical point of view, the estimation of the different components in expression (5) is feasible when reliable panel data set and inputs prices (costs), among others are available. In our case data on input prices are not available and under these conditions allocative efficiency, cost efficiency and price adjustment effects cannot be estimated.

However, the Tunisian olive growing farms output production growth can be decomposed into aggregate input growth, technical change and changes in technical efficiency using Farrell's (1957) and Lachaal (1994) decomposition of productive efficiency. The decomposition of a general form of equation (1) makes it possible to understand the importance of each one of these components in total production growth:

$$Y = F(X,t) \tag{6}$$

Where;

Y : output production.

X : vector of k inputs used in the production process (k =1, … K).

*t* : variable represent neutral technical change.

According to Farrell (1957), technical efficiency (TE) is defined as:

$$TE = \frac{Y}{F(X,t)} \quad \text{Where } 0 < TE \leq 1 \tag{7}$$

Taking the logarithm time derivate of both sides of equation (7) yields:

$$\dot{TE} = \dot{Y} - \sum_{i=1}^{k} \frac{\partial Ln\, F(X,t)}{\partial X_i} \frac{dX}{dt} - \frac{\partial Ln\, F(X,t)}{\partial t} \tag{8}$$

Taking into account that the rate of technical change ($\dot{TC}$) is defined as:

$$\dot{TC} = \frac{\partial LnF(X,t)}{\partial t} \tag{9}$$

Equation (8) can be reformulated in the following way:

$$\dot{Y} = \dot{TE} + \dot{TC} + \sum_{i=1}^{k} \frac{\partial F(X,t)}{\partial X_i} \frac{X_i}{F(X,t)} \dot{X}_i \tag{10}$$

The first term on the right hand side captures the effect of changes in technical efficiency on production growth. The second term represents technological change effect. Whereas the last term indicates the effect of input change on production growth, approximated by the sum of input growth rates weighted by the relevant production elasticities.

### 5.2. Frontier production function

To investigate the decomposition of output growth in Tunisia's olive-growing farms, we use a production frontier function. The function is approximated by the quasi-translog functional form, proposed by Fan (1991) and Karagiannis and Tzouvelekas (2001). When panel data are available, the function takes the following form:

$$y_{it} = \beta_0 e^{\beta_T t + 0.5\beta_{TT} t^2} \prod_{j=1}^{K} x_{jit}^{(\beta_j + \beta_{jT} t)} e^{v_{it} - u_{it}} \qquad (11)$$

Or,

$$ln\ y_{it} = ln\ \beta_0 + \beta_T t + 0.5\beta_{TT} t^2 + \sum_{j=1}^{K} \beta_j\ ln\ x_{jit} + \sum_{j=1}^{K} \beta_{jT}\ ln\ x_{jit} t + v_{it} - u_{it}$$

where $i = 1,...,N$ denotes farms in the sample, $t = 1,\dots,T$ represents time periods, $j = 1,...,K$ are the conventional inputs used in the production process, $\beta$ are the parameters to be estimated, $v_{it} \sim N(0,\sigma_v^2)$ is a symmetric and normally distributed error term (*i.e.*, statistical noise) which represents those factors that cannot be controlled by farmers and left-out explanatory variables; and $u_{it} \sim N_+(\mu,\sigma_u^2)$ is an independently and identically distributed one-sided random error term representing the stochastic shortfall of the $i^{th}$ farm output from its production frontier due to the existence of technical inefficiency (*i.e.*, farm-specific output-oriented technical inefficiency). It is further assumed that the two error terms are independently distributed from each other.

The temporal pattern of $u_{it}$ as the changes in technical efficiency over time rather than the degree of technical efficiency *per se* matters. For this purpose Battese and Coelli (1992) specification is adopted to model the temporal pattern of technical inefficiency, *i.e.*,

$$u_{it} = \left\{ exp\left[ -\xi \left( t - T \right) \right] \right\}\ u_i$$

Where $\xi$ captures the temporal variation of individual output-oriented technical efficiency ratings, and $t \in [1,2,...,T]$. If the parameter $\xi$ is positive (negative), technical efficiency tends to improve (deteriorate) over time. If $\xi = 0$, output-oriented technical efficiency is time-invariant. The above production frontier function can be estimated by single-equation methods under the assumption of expected profit maximization.

## 6. Results and Discussion

As we posed at the outset, the output in the *translog* production function in (11) represents the annual production of olives in metric tons. Inputs considered in the model are capital, total labour and intermediate consumption. All inputs are measured in Tunisian Dinar. Summary statistics of these variables is given in table 1.

**Table 1**: Summary statistics of variables used in the frontier model for olive growing farms in Tunisia.

| Variables | Mean | Standard Deviation | Min. | Max. |
|---|---|---|---|---|
| Olives (MT)[1] | 21.37108 | 56.85210 | 0.09000 | 560.0000 |
| Capital (TD)[2] | 176420.9 | 405467.7 | 1699.000 | 2975001 |
| Labour (TD) | 468.8240 | 1307.811 | 7.0000 | 13330.00 |
| Intermediate Consumption (TD) | 874.8258 | 2163.351 | 10.5000 | 18900.00 |

Source: Own elaboration from olive growing farms in Tunisia.
Note: (1) MT: Metric Tons; (2) TD: Tunisian Dinar (1TD = 0.625 euros).

Maximum likelihood estimates of the parameters of the *translog* frontier production model are obtained using the computer package FRONTIER version 4.1 (Coelli, 1996). Parameter estimates, along with the standard errors of the ML estimators of the Tunisian olive growing farms frontier model are presented in table 2.

The signs of the estimated parameters of the *translog* frontier production model are as expected. Estimated coefficients for all inputs such as capital, labour and intermediate inputs are positive and significant, which confirms the expected positive relationship between capital, labour and intermediate inputs and olive production.

In addition, the ratio of farm specific variability to total variability is positive and significant at the 5% level, implying that farm specific technical efficiency is important in explaining the total variability of output produced. This justifies the empirical use of the stochastic production function.

**Table 2**: ML estimates of the *translog* production frontier function for olive growing farms in Tunisia.

| Parameters | Estimates | Standard error |
|---|---|---|
| $\beta_0$ | 0.2559 | (0.1279)** |
| $\beta_K$ | 0.6590 | (0.0566)** |
| $\beta_L$ | 0.0069 | (0.0201) |
| $\beta_{IC}$ | 0.2183 | (0.5455)** |
| $\beta_{KT}$ | -0.0827 | (0.1035) |
| $\beta_{LT}$ | -0.0032 | (0.0392) |
| $\beta_{ICT}$ | 0.2499 | (0.1012)** |
| $\beta_T$ | 0.9862 | (0.2008)** |
| $\beta_{TT}$ | 1.2880 | (0.2217)** |
| $\sigma^2 \cong \sigma_v^2 + \sigma_u^2$ | 0.4501 | (0.0450)** |
| $\gamma = \sigma_u^2/\sigma^2$ | 0.1114 | (0.0470)** |
| $\xi$ | 0.5182 | (0.1005)** |
| $\mu$ | 0.447 | (0.1027)** |
| Log-Likelihood | -591.176 | |

Notes: K refers to capital, L to labor and IC to intermediate consumption. * Significant at 1% level of significance; ** Significant at 5% level of significance.

Further, a number of statistical tests of hypotheses for the production frontier model parameters are carried out and results are presented in table 3[1]. The statistical significance of modelling farm effects is examined using likelihood ratio tests.

Firstly, the validity of the *translog* specification over the conventional average production is strongly accepted. In other terms, the conventional average production does not represent adequately the structure of olive growing farms in Tunisia and the traditional average response model in which farms are assumed to be fully technically efficient is rejected. The null hypothesis $\gamma = \mu = \xi = 0$ is rejected at the 5% level of significance.

The second null hypothesis of stochastic production frontier (SPF) model with time invariant output-oriented technical efficiency (i.e., $H_0 : \mu = \xi = 0$) is also rejected at the 5% level of significance. Moreover, testing the null hypothesis, which specifies that stochastic production frontier model (SPF) with time varying output oriented technical efficiency (i.e., $H_0 : \mu = 0$) is also possible. Results in table 5 showed that this hypothesis is rejected at the 5% level.

**Table 3**: Tests of hypotheses for the parameters of the production frontier function for olive growing Farms in Tunisia.

| Hypothesis | LR test-statistic | Critical Value ($a$ = 0.05) |
|---|---|---|
| Average Production Function, *i.e.*, $\gamma = \mu = \xi = 0$ | 47.58 | $\chi^2_3 = 7.81$ |
| Aigner *et al.*, (1977) SPF model with time-invariant output-oriented technical efficiency, *i.e.*, $\mu = \xi = 0$ | 25.05 | $\chi^2_2 = 5.99$ |
| Aigner *et al.*, (1977) SPF model with time-varying output-oriented technical efficiency, *i.e.*, $\mu = 0$ | 40.86 | $\chi^2_1 = 3.84$ |
| Time-invariant output-oriented technical efficiency, *i.e.*, $\xi = 0$ | 29.07 | $\chi^2_1 = 3.84$ |
| Constant returns-to-scale, *i.e.*, $\sum_j \beta_j = 1$ and $\sum_j \beta_{jT} = 0$ | 28.17 | $\chi^2_4 = 9.49$ |
| Hicks-neutral technical change, *i.e.*, $\beta_{jT} = 0 \ \forall j$ | 29.07 | $\chi^2_3 = 7.28$ |
| Zero-technical change, *i.e.*, $\beta_T = \beta_{TT} = \beta_{jT} = 0 \quad \forall j$ | 80.86 | $\chi^2_5 = 11.1$ |

The hypotheses that efficiency is invariant over time (i.e., $H_0 : \xi = 0$ ) is also tested. The null hypothesis is strongly rejected at the 5% level of significance. Thus, output-oriented technical efficiency is time variant. The estimated parameter $\xi$ is positive and technical efficiency tends to improve over time.

Sine the hypothesis of constant returns to scale is rejected at the 5% level of significance, the scale effect should be contributing to total factor productivity changes and output growth. In this case, the scale effect is positive as the farms in the sample exhibited

[1] All tests of hypotheses are obtained using a Maximum Likelihood-Ratio Statistic. This statistic has a chi-square distribution and is defined by $\lambda = -2(Ln\,L(H_0) - Ln\,L(H_1))$, where $L(H_0)$ and $L(H_1)$ are the values of the likelihood function under the specification of the null hypothesis, $H_0$, and the alternative hypothesis, $H_1$.

increasing returns to scale and the aggregate output index increased over time and *vice versa*. Moreover, the hypothesis of Hicks neutral technical change is rejected at the 5% level of significance. This means that non neutral component dominated the neutral one. This is true for the non neutral component has an average of 0.112%, whereas the neutral component has an average of only 0.0935%. On the other hand, the hypothesis of zero technical change is rejected at the 5% level of significance (i.e., $H_0 : \beta_T = \beta_{TT} = \beta_{jT} = 0 \quad \forall j$). Thus, technical change is contributing to total factor productivity changes. The neutral component of technical change is found to be progressive at a constant rate as the estimates for the parameters $\alpha_T$ and $\alpha_{TT}$ are both positive and statistically significant at the 5 per cent level.

The next step after the hypotheses testing consists of estimating the different partial production elasticities with respect to production factors. Estimation results are showed in table 4.

Marginal products indicated that, on average, capital impact factor is greater than labour and intermediate inputs factors. The value of these elasticities for capital, labour and intermediate inputs are 0.6, 0.0072 and 0.19, respectively. Theses results indicated that capital has contributed the most to olive oil production followed by labour and intermediate consumption. It appears also that production elasticities of capital and labour are decreasing: capital by 6.6% and labour by 22.2%. The annual rate of increase for intermediate consumption input, 86.7% is greater than the rates of decrease for capital and labour inputs. These results reflect the economic reality of olive producing farms in the region, subject of study. Indeed, olives production is principally related with capital and with intermediate inputs. The labour input labour appears with a minimal effect on the production since the high use of family labour in the olive production.

**Table 4**: Production elasticities of capital, labor and intermediate consumption used in olive growing farms in Tunisia.

| Years | Capital | Labour | Intermediate consumption |
|---|---|---|---|
| 1995 | 0.71 | 0.009 | 0.01 |
| 1996 | 0.66 | 0.007 | 0.22 |
| 1997 | 0.62 | 0.005 | 0.34 |
| Mean | 0.66 | 0.007 | 0.19 |

Source: Author's own elaboration.

The estimated mean technical efficiency was found increasing rather slowly from 32.15% in 1995 to 48.8% in 1996 (table 5). However, these mean increase rapidly from 1996 (48.8%) to 1997 (64.3%), implying that its contribution to output growth would be relatively important in this period. However, during the consideration period of analysis (1995-1997), most farms in the sample (85.4%) have consistently achieved efficiency scores greater than 50%.

The computed average technical efficiency is 48.4% during the period 1995-1997, ranging from a minimum of 24.8% to a maximum of 84.6%. Given the present state of technology and input levels, this suggests that farms in the sample are producing on average at 48.4% of their potential. This suggests that olive producers may increase their production by as much as 51.5% through more efficient use of production inputs.

According to the results reported in table 5, the production is characterised by decreasing returns to scale, which on average was 0.8 during the period of study (1995-1997). This implies that the contribution of the scale effect to output growth would be negative as far as output increases. In this case, scale economies don't stimulate output growth even in the presence of improvements in technical efficiency with input use increases.

**Table 5**: Measures of technical efficiency for Tunisian olive growing farms.

| TE (range %) | 1995 | 1996 | 1997 |
|---|---|---|---|
| <20 | 36 | 0 | 0 |
| 20-30 | 59 | 7 | 0 |
| 30-40 | 38 | 38 | 0 |
| 40-50 | 21 | 62 | 15 |
| 50-60 | 17 | 35 | 39 |
| 60-70 | 7 | 20 | 75 |
| 70-80 | 0 | 14 | 30 |
| 80-90 | 0 | 2 | 18 |
| 90 > | 0 | 0 | 1 |
| N | 178 | 178 | 178 |
| Mean | 32.15 | 48.88 | 64.34 |
| Min. | 9.04 | 23.44 | 41.86 |
| Max. | 77.45 | 85.45 | 90.88 |
| Returns to scale | | | |
| | 0.736 | 0.884 | 0.970 |

The decomposition analysis results of output growth during the period 1995-1997 are given in table 6. An average annual rate of 0.75% was observed for output growth. Our empirical findings suggest that this growth stems mainly from the corresponding increase in aggregate input (51.5%), which increased at an average rate of 0.4%. The remaining 48.5% is attributed to productivity growth growing at an average annual rate of 0.3%.

Results suggest also that total factor productivity increased at an average annual rate of 0.3% between 1995 and 1997. About 56% of the total change is attributed to technological progress and 44% is attributed to change in technical efficiency. The average annual rate of technical change is found to be 0.2% with an almost equal contribution by the biased (0.1%) and the autonomous (0.09%).

As indicated above, the input changes effects are highly significant on total production growth (51.5%). The increases in labour use explain 46.6% of total production growth. It contributed, on average, with the highest amount to total input growth (90.5%). The increase in intermediate consumption input has a relative considerable effect. Whereas, the effect of capital on total input growth is negligible.

**Table 6**: Decomposition of Output Growth for Tunisian Olive-Growing Farms (average values for the 1995-1997 period).

| | Average Annual Rate of Change | (%) |
|---|---|---|
| Output Growth | 0.75 | 100 |
| Aggregate Input Growth | 0.39 | 51.52 |
| Capital | 0.0006 | 0.08 |
| Labour | 0.35 | 46.61 |
| Intermediate Consumption | 0.03 | 4.83 |
| Total Factor Productivity Growth | 0.36 | 48.47 |
| Technical Change Effect | 0.20 | 27.15 |
| *Neutral* | *0.09* | *12.38* |
| *Biased* | *0.11* | *14.83* |
| Change in Technical Efficiency | 0.16 | 21.32 |

These findings are considered consistent with the reality taking into account the short period of the panel (3 years) and the perennial cycle of the olive tree. In addition, the contribution of change in technical efficiency becomes important on output growth since its relative contribution is almost 21.3%. Notice also that technical efficiency grew with an average annual rate of 0.16%.

## 7. Conclusions and Policy Implications

In this paper, we investigate farm level technical efficiency of production and the relative contribution of technical efficiency, technological change and increased input use to output growth in the Tunisian olive growing sector using a stochastic frontier production function approach applied to panel data for the period 1995-1997. The proposed methodology is based on the use of a flexible *translog* functional form.

Estimation results among the different functional forms revealed that the *translog* specification is the best representation of technology in the olive growing sector in Tunisia. The estimated coefficients of capital, labour and intermediate consumption inputs are positive and significant for capital and intermediate consumption inputs and, non significant for labour. To asses the impacts of these factors, partial production elasticities were calculated. Empirical findings indicate that capital has contributed the most to olive oil production followed by labour and intermediate consumption. These results reflect the economic reality of olive producing farms in the study region. Indeed, olive production is principally related to capital and intermediate inputs. The labour input appears with a minimal effect on production given the high use of family labour in olive production.

Indeed, the contribution of capital (proxied with land value) is expected to decrease in the future due to land parcelling. In this aspect, decisions makers need to set up land programs in order to avoid parcelling and bring together small farmers in a cooperative system. Further, the quantity increase of labour will only have limited effect on olive production. Thus, the improvement of labour quality is the unique way for considerable olive production growth. In practice skilled labour and agricultural training particularly used for pruning are associated with higher levels of technical efficiency. This highlights the need for government policies, through extension activities, to set up training programs on conducting olive plantation, in general, and improving pruning techniques, in particular.

Empirical findings show that estimated technical efficiency of olive production in the sample varied widely, ranging from a minimum of 24.8% to a maximum of 84.6%, with a mean value of 48.5%. This suggests that, on average, olive producing farmers could increase their production by as much as 51.54% through more efficient use of production inputs. This result implies that improvement of technical efficiency should be the first logical step for considerably increasing olive production in the study region. Further, considering that international competition is increasing and environment regulations are being tightened, the potential for increasing production by using more traditional inputs is limited.

Further, the increase of modern inputs (fertilizers, pesticides, chemical products, etc..) is dissuaded due to environmental concerns. However, increase of machinery use would certainly have a considerable effect on technical efficiency. This is particularly true for the machinery used for irrigation but only 27% of farms irrigate. Two reasons are related to this; the high cost of irrigation equipment machinery and the limited availability of water resources. This highlights the need for government policies to encouraging investment in this type of machinery by facilitating to access to credit. Moreover, irrigation operations should be encouraged whenever water is available.

Growth accounting for production showed that a significant share of total production growth is attributed to increases in traditional inputs. Total input growth explained 51.5% of total production growth. These findings indicate that farmers hose an expensive way to increase their production. Theses findings can have some policy implications. First, the unique and best way to increase output is to improve total factor productivity. Second, we have clearly identified the sources of productivity growth. On the other hand, technological change accounted for 27.5% of total production growth. Compared to other determinant, this proportion is still important. Thus, an increase in investment in the olive growing farms, especially in research and development, is needed to stimulate technological change and therefore increase total factor productivity. However, the introduction of technological innovations must not be accompanied only by a continuous assistance for farmers by the government and private operators but must also take into account the real condition of olive growing farmers.

Finally, the contribution of technical efficiency in output growth stood at 21.3% and grew at an average annual rate of 0.16%. However, this contribution efficiency can be improved not only through the efficient use of inputs but also by the conception of practical and feasible strategies including all involved partners in the olive oil sector (farmers, decisions makers, private sector, olive oil exporters, etc..).

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