AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

Productive Efficiency in Water Usage:

An Analysis of Differences among Citrus Producing Farms Sizes in Tunisia

By

Dhehibi, Boubaker

Poster presented at the Joint 3rd African Association of Agricultural Economists (AAAE) and 48th Agricultural Economists Association of South Africa (AEASA) Conference, Cape Town, South Africa, September 19-23, 2010

Productive Efficiency in Water Usage: An Analysis of Differences among Citrus Producing Farms Sizes in Tunisia

Boubaker DHEHIBI•
Department of Agricultural Economics
National Research Agronomic Institute of Tunisia
Rue Hedi Karray, Ariana 2049, Ariana, Tunisia
Phone: (+ 216) 71 230-024 / 71 230-239 - Fax: (+ 216) 71 752-897 / 71 716-537
E-mail.: bdhehibi@aragon.es / bdhehibi07@webmails.com

Paper prepared to be presented to the "African Association of Agricultural Economists Congress - Africa and the Global Food and Financial Crises"
19 - 23 September 2010, Cape Town, South Africa

Abstract - The objective of this paper is to measure productive efficiency of irrigation water efficiency based on the concept of technical efficiency and compared among different sizes farms. The proposed methodology is applied to a randomly selected sample of 144 citrus growing farms located in Nabeul (Tunisia) and differentiated by size (small, medium and large farms). A stochastic production frontier approach, based on Battese and Coelli's (1995) inefficiency effect model, is used to obtain farm-specific estimates of technical and irrigation water efficiency. The last step of the analysis consists on the identification of the factors influencing irrigation water efficiency differentials across citrus growing farms on the basis on a second-stage regression approach.

Empirical results show that estimated mean technical efficiency ranges from a minimum of 12.82% to a maximum of 90.69% with an average estimate of 67.73%. This result means that 32.3% increase in production is possible with the present state of technology and unchanged input uses, if technical inefficiency is completely removed. Thus, improving technical efficiency will result to significant increases in framer's revenue and profit.

On the other hand, mean irrigation water efficiency is found to be 53%, which is much lower than technical efficiency and also exhibits greater variability ranging from 1.6% to 98.87%. The estimated mean irrigation water efficiency implies that the observed quantity of marketable citrus could have been maintained by using the observed values of other inputs while using 47.0% less of irrigation water. This means that farmer's can achieve significant savings in water use by improving the utilisation of irrigation system and by utilizing more advanced irrigation technologies.

Keywords: Water Efficiency, stochastic frontier production function, small, medium and large citrus farms, Tunisia.

•Corresponding author: Department of Agricultural Economics, INRAT. Rue Hédi Karray, 2049 Ariana, Tunisia. Phone: + 216 71 230-024 / 71 230-239 - Fax: + 216 71 752-897 / 71 716-537.
Email: bdhehibi@aragon.es.

1. Introduction

Irrigation water is becoming an increasingly scare resource for the agricultural sector in many regions and countries. A common ground in past policy schemes was the development of adequate irrigation infrastructure to guarantee the supply of irrigation water as the demand for agricultural products was increasing. However, these expansionary policies have resulted in a massive use of irrigation water at a heavily subsidized cost and physical scarcity. Water scarcity has become an increasing social and economic concern for policy makers and competitive water users. Particularly, agriculture is becoming the sector to which policy makers are pointing out at the core of the water problem.

Tunisian reserves of water are approximately estimated at 4.7 Billion m^3/year. 2.7 Billion m^3 coming from annual rivers in the north, 0.7 Billion m^3 as groundwater in the Center, the plains and the coastal area and approximately 1.3 Billion m^3 in the deep tablecloths mainly in the south. Water resources are unevenly distributed across the country with around 60% located in the North, 18% in the Center, and 22% in the South. Water resources that have a salinity of less than 1.5 g L-1 are distributed as follows: 72% of surface water resources, 8% of shallow groundwater, and 20% of deep groundwater. Water resources management and planning are outlined in the country's five-year development plans. The goals are to mobilize most of the surface water through the completion of 42 dams and the construction of 203 hillside-dams, 1000 hillside-lakes, and 4000 recharge and floodwater diversion structures. The planned infrastructure in the year 2010, will account 87% of the potential (4760 Mm^3). In addition, the plans emphasize water harvesting and wastewater reutilization.

Taking into account the limited water resources and the disparity between supply and demand often generated in conditions of dryness, Tunisia has engaged over the last three decades in a dynamic program of water mobilization. Several investment projects were granted reaching 9% of the total investments of the state in the VIII plan of development (1992-1996). Agriculture remains as the biggest water consuming sector (more than 80% of the total demand) and accounts for approximately 12% of the GDP.

Irrigated agriculture represents 35% of the output value derived from the agricultural sector, 20% of exports and 27% of agricultural employment (Ministry of Agriculture and Water Resources, 2003). Irrigated perimeters, contribute to 95% of the vegetable production, 70% of fruits and 30% of the dairy output. The average efficiency of the irrigation networks is relatively weak. It is estimated approximately 50% (Bachta and Ghersi, 2004).

The irrigated areas with those types of waters cover 411.4 thousand ha. Tree crops are first with an area of 152.6 thousand ha, which corresponds to 37% of the total surface. Vegetables are second with 30%. They are followed by forages (16%), cereals (16%) and other industrial crops (1%). The industrial sector and the tourism retain 5% and 1% of water resources, respectively. The service of water-drinking represents 11% in rural area; the service rate reached 80 % in 2000, whereas it did not exceed 38% in 1990.

The objective of this paper is to measure the productive efficiency of water irrigation efficiency based on the concept of input- specific technical efficiency methodology proposed by Karagiannis *et al.,* (2003). In addition, the paper presents a comparative analysis of the productivity of water use efficiency of small, medium and large citrus producing farms. The proposed measure is a non- radial, input-oriented measure of input –specific technical efficiency. It has an economic rather than an engineering meaning and it is defined as the ratio of the minimum feasible water use to observed water use, conditional on production

technology and observed levels of output and other inputs used. It provides information on how much water use could be decreased without altering the output produced and the quantities of other input used. This measure explicitly recognizes that each irrigation system could be technically inefficient for several reasons that can be explored through statistical methods.

The remainder of this paper is organized as follows. In section 2, we present the methodological framework paying special attention to the measurement of technical efficiency. Section 3 outlines the irrigation water efficiency measurement. The empirical model as well as the data and variables used in the empirical model are presented in section 4. Section 5 presents the empirical results and discussions and section 6 concludes with some remarks on policy implications.

2. Theoretical Background: Stochastic Production Frontier

Since the stochastic production frontier model was first, and nearly simultaneously, published by Meeusen and van den Broeck (1977) and Aigner, Lovell and Schmidt (1977), there has been considerable research to extend the model and explore exogenous influences on producer performance. Early empirical contributions investigating the role of exogenous variables in explaining inefficiency effects adopted a two-stage formulation, which suffered from a serious econometric problem[1].

Recently, Kumbhakar, Ghosh and McGuckin (1991), Reifschneider and Stevenson (1991) and Huang and Liu (1994) proposed stochastic production models that simultaneously estimate the parameters of both the stochastic frontier and the inefficiency functions. While the formulated models differ somewhat in the specification of the second error component, they all used a cross section data. Battese and Coelli (1995) formulated a stochastic frontier production model similar to that of Huang and Liu and specified for panel data. In this study, we adopt the Battese and Coelli model but specified for a cross section data context. The model consists of two equations (1) and (2). The first equation specifies the stochastic frontier production function. The second equation, which captures the effects of technical inefficiency, has a systematic component $\delta' z_i$ associated with the exogenous variables and a random component ε_i :

$$LnY_i = Ln\, f(x_i\,;\beta) + v_i - u_i \qquad (1)$$

$$u_i = \delta' z_i + \varepsilon_i \qquad (2)$$

Where Y_i denotes the production of the i-th firm; x_i is a vector of input quantities of the i-th firm and β is a vector of unknown parameters to be estimated. The non-negativity condition on u_i is modelled as $\varepsilon_i \sim N(0, \sigma_\varepsilon^2)$ with the distribution of ε_i being bounded below by the truncation point $-\delta' z_i$. Finally, v_i are assumed to be independent and identically distributed N (0, σ_v^2) random errors, independent of the u_i .

The parameters of the stochastic frontier production function in (1) and the model for technical inefficiency effects in (2) may simultaneously be estimated by the maximum

[1] In the first stage of this formulation, the stochastic frontier model is estimated and the residuals are decomposed using the Jondrow *et al.* (1982) technique. The estimated inefficiency scores are then regressed, in a second stage, against the exogenous variables contradicting the assumption of identically distributed inefficiency of the first stage.

likelihood method. The technical efficiency of production for the i-th farm can be defined as follows:

$$TE_i = \exp(-u_i) = \exp(-\delta' z_i - \varepsilon_i) \quad (3)$$

A predictor for which is provided by its conditional expectation[2]:

$$E\left[\exp\{-u_i\} \mid (v_i - u_i)\right] = \left[\exp\left\{-\mu_{*i} + \frac{1}{2}\sigma_*^2\right\}\right] \cdot \left[\frac{\Phi\left[(\mu_{*i}/\sigma_*) - \sigma_*\right]}{\Phi(\mu_{*i}/\sigma_*)}\right] \quad (4)$$

Where,

$$\mu_{*i} = \frac{\sigma_v^2(\delta' z_i) - \sigma_u^2(\varepsilon_i)}{\sigma_v^2 + \sigma_u^2} \quad (5)$$

$$\sigma_*^2 = \frac{\sigma_v^2 \sigma_u^2}{\sigma_v^2 + \sigma_u^2} \quad (6)$$

3. Measuring Irrigation Water Efficiency

In order to achieve the mentioned objectives, we have used and applied the methodology developed by Karagiannis *et al.,* (2003) for a cross section data from survey conducted into the most principal Tunisian citrus sector production. According to Karagiannis *et al.,* (2003), the methodological framework of technology be described by the following stochastic production frontier function:

$$y_i = f(x_i, w_i,; a) \exp(\varepsilon_i \equiv v_i - u_i) \quad (7)$$

Where i = 1,2,....,N refers to farms, y is the quantity of output produced, x is a vector of input quantities used, w is irrigation water, and ε_i is a composed error term consisting of a symmetric and normally distributed error term, v_i, respecting those factors that cannot be controlled by farmers (i.e., weather effects).

Then, farm specific estimates of output-oriented technical efficiency are obtained as $TE_i^0 = \exp(-u_i)$ (Kumbhakar and Lovell, 2000), while farm-specific estimates of input oriented technical efficiency are derived by equation (7) with $y_i = f(v_i x_i, v_i w_i; \alpha) \exp(v_i)$ and solving for $TE_i^1 = v_i$ (Atkinson and Cornwell, 1994; Reinhard *et al.,* 1999). Thus, TE_i^0 is greater, equal, or less than TE_i^1 whenever returns to scale are decreasing, constant, or increasing, respectively (Fâre and Lovell, 1978).

The above measures of efficiency are incapable of identifying the efficient use of individual inputs. For this reason, the proposed irrigation water efficiency measure is based on the non-radial notion of input specific technical efficiency (Kopp, 1981). Specially, it is defined as the ratio of minimum feasible to observed levels of outputs and input. Thus, irrigation water efficiency is an input-oriented, single-factor measure of technical efficiency defined as:

$$IE^1 = [\min\{\lambda : f(x, \lambda w; a) \geq y\}] \rightarrow (0, 1) \quad (8)$$

Irrigation water efficiency, as defined in (8), has an input-conserving interpretation, which however cannot be converted into a cost saving measure due to its non radial nature (Kopp, 1981). The proposed measure of irrigation water efficiency is illustrated in figure 1 (Karagiannis *et al.,* 2003).

[2] For the derivation of the likelihood function, its partial derivatives with respect to the parameters of the model and an expression for the predictor of technical efficiency see Battese and Coelli (1993).

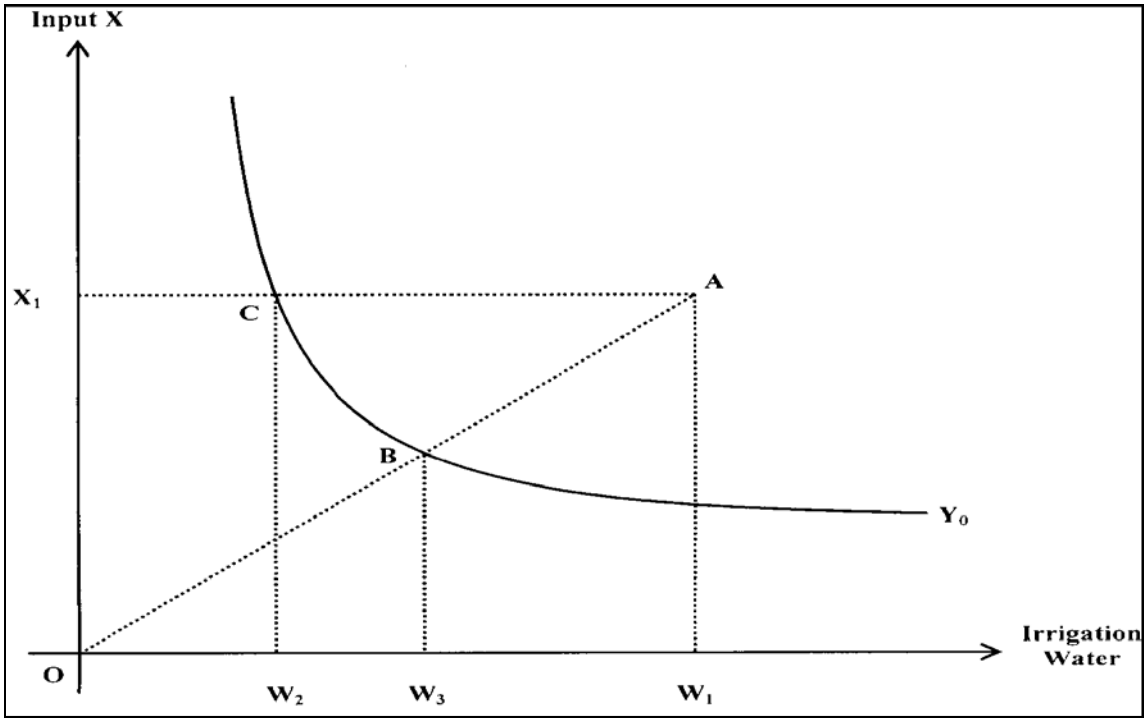

Figure 1: proposed measure of irrigation water efficiency.

Let the ith inefficient farmer producing output Y_0 by using x_1 of all other inputs and w_1 units of irrigation water. Then $TE_i^{\,1}$ = OB /OA and $IE_i^{\,1} = x_1$ C/ x_1 A $=w_2 / w_1$. The proposed irrigation water efficiency measure determines both the minimum feasible water use (w_2) and the maximum possible reduction in water use ($w_1 - w_2$) that still permits the production of Y_0 units of output with unaltered the use of all other inputs. On the other hand, according to the $TE_i^{\,1}$ measure, the maximum possible reduction in water use, required to make the ith farm technically efficient, is ($w_1 - w_3$). From figure 1, it is clear that the former ($w_1 - w_2$) will always be greater than the latter ($w_1 - w_3$). Consequently, the maximum possible reduction in water use suggested by $IE_i^{\,1}$ should be considered as an upper bound (Akridge, 1989).

Conceptually, measurement of $IE_i^{\,1}$ requires an estimate for the quantity (w_2), which is not observed. Nevertheless, using $IE_i^{\,1} = w_2 / w_1$ it can easily be seen that $w_2 = w_1 . IE_i^{\,1}$. By substituting this into (1) and by noticing that point C in Figure 1 lies on the frontier, i.e., u_i = 0, (7) may be rewritten as:

$$y_i = f(x_i, w_i^E; a) \exp(u_i) \qquad (9)$$

Where $w_i^E = w_2$ (Reinhard *et al.,* 1999). Then, a measure of $IE_i^{\,1}$ can be obtained by equating (7) with (9) and by using the econometrically estimated parameters α.

Since $IE_i^{\,1}$ is a non radial efficiency measure that does not have a direct cost-saving interpretation, the single-factor technical cost efficiency measure could instead be used to evaluate the potential cost savings accruing to more effective management of a single factor (Kopp, 1981). Then, irrigation water technical cost efficiency, $ITCE_i$, could be defined as the potential cost savings from adjusting irrigation water to a technically efficient level while holding all other inputs at observed levels. Following Akridge (1989), farm-specific estimates of $ITCE_i$ may be obtained as:

$$ITCE_i = S_{wi} IE_i^I + \sum_{j=1}^{J} S_{ji} \quad (10)$$

Where S_{wi} and S_{ji} are the ith farm's observed input cost shares for irrigation water and the jth input, respectively. Given that $0 < IE_i^I \leq 1$ and $S_{wi} IE_i^I + \sum_{j=1}^{J} S_{ji} = 1$ for all i, $0 < ITCE_i \leq 1$. However, cost saving will vary with factor prices and relatively inefficient water use in a physical sense can be relatively efficient in a cost sense, and vice versa (Kopp, 1981).

4. Empirical Model

4.1. Model Specification

Let the unknown production frontier (7) to be approximated by the following *Cobb-Douglas* specification:

$$\ln y_i = \alpha_0 + \sum_{j=1}^{J} \alpha_j \ln x_{ji} + \alpha_w \ln w_i + v_i - u_i \quad (11)$$

Using the Battese and Coelli's (1995) inefficiency effect model, the one sided error term is specified as:

$$u_i + g(z_i; \delta) + w_i \quad (12)$$

Where z is a vector of variables used to explain efficiency differentials among farmers, δ is a vector of parameters to be estimated (including an intercept term), and w_i is an *iid*. The model (11) and (12) can be estimated econometrically in a single stage using ML techniques and the frontier (version 4.1) computer package developed by Coelli (1992). The variance parameters of the likelihood function are estimated in term of $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \frac{\sigma_u^2}{\sigma^2}$, where the γ parameter has a value between zero and one.

Using the estimated parameters and variances, farm-specific estimates of TE_i^0 are obtained as:

$$TE_i^0 = E\{\exp(-u_i / \varepsilon_i)\} = \exp\left[\left(-\mu_i^0 + 0.5 G_0^2\right)\left(\frac{\phi\left[\left(\mu_i^0 / G_0\right) - G_0\right]}{\phi\left(\mu_i^0 / G_0\right)}\right)\right] \quad (13)$$

Where

$$\mu_i^0 = \frac{G_v^2 \mu_i - G_u^2 \varepsilon_i}{G_v^2 + G_u^2}, \; G_0^2 = \frac{G_u^2 G_v^2}{G_u^2 + G_v^2}$$

Φ is the cumulative density function of the standard normal random variable and E is the expectation operator.

On the other hand, farm specific estimates of IE_i^1 are derived by using (9) and the following relations developed by Reinhard *et al.*, (1999) and applied for the *Cobb-Douglas* specification case (11):

$$IE_i^I = \exp\left[\left\{-\xi_i \pm \left(\sqrt{\xi_i^2 - 2\alpha_{ww} u_i}\right)\right\} / \alpha_{ww}\right] \quad (14)$$

Where

$$\xi_i = \frac{\partial \ln y_i}{\partial \ln w_i} = \alpha_w + \sum_{j=1}^{J} \alpha_{jw} + \ln x_{ji} + \alpha_{ww} \ln w_i$$

4.2. Data and Variables Definitions

A cross section data of 144 Tunisian citrus producing farms covering the 2002-2003; 2003-2004 and 2004-2005 periods are collected from surveys conducted in 2 delegations of the governorate of Nabeul, Tunisia (table 1). The choice of this region is justified by its importance in the national citrus production, transformation and exports sector. Indeed, according to the Ministry of Agricultural statistics, this region represents 1.7% of national agricultural land; it contributes for 80% for national citrus production and for more than 90% for national citrus exportation.

Table 1: Distribution of citrus farms surveyed by delegation and by land area.

Delegations	**Private Farms**			
	< 1Ha	1 - 2 ha	> 2ha	Total
Beni Khalled	20	31	19	70
Menzel Bouzelfa	12	27	35	74
Total Nabeul	32	58	54	144

Source: Own elaboration from citrus producing farms in Tunisia.

The selected sample comprises 32 farms of size lower than 1 ha (witch represent 22.22%), 58 of size ranging between 1 and 2 ha (40.27%) and 54 of size higher than 2 ha (37.50%). It represents a total agricultural surface of about 392.22 ha. Citrus growing manpower adds up 105921 productive citrus trees witch 8.63% are of age lower than 5 years, 8.49% of age ranging between 5 and 10 years, 19.23% of age ranging between 10 and 20 years and 63.6% of age higher than 20 years. The density of plantation is about 270 trees/ha on average. The production of citrus during 2002/2003, 2003/2004 and 2004/2005 was 2390.7 metric tons per year, on average, witch correspondent to 67.7Kg/tree and 18.3MT/ha.

As we posed at the outset, the dependent variable is the total annual citrus production measured in Kg. The aggregate inputs considered in the analysis are: (1) land, measured in hectares; (2) total labour measured in working days; (3) chemical inputs measured in Tunisian Dinars; (4) irrigation water measured in m^3; and (5) other costs, comprising the rest of inputs used in producing citrus (mechanisation, etc.) measured in Tunisian Dinars. Summary statistics of these variables is given in table 2. From the surveyed farms, it appears that the average age of respondents is 55.8 years, ranging from 29 to 80. It is also important to indicate that on average, land holding is 2.61 ha, ranging from 0.2 to 18.5. 35.33% of the sample farmers are illiterate, 30.66 are with primary level, whereas 34.00% accumulated at least 6 years of schooling.

In terms of structure of land, it appears that 81.33% of sample farmers are successors of farms, the other 18.66% are purchasers. 86.00% of farmers never followed a training program on conducting citrus plantation and improving conduct techniques. Moreover, only 71% of farmers are agreeing with the disposable of water especially in summer period. A significant part of surveyed farmers (90.6%) make resort for fertilization operations. It is important to indicate the high level of family labour with respect to total labour (68.65%), especially for citrus speculation (82.38%). Finally, in terms of machinery, only 28.00% of sample farmers have tractors. The other 72.00% make resort to the hiring.

Table 2: Summary statistics of the variables used in the Frontier Model for citrus producing farms in Tunisia.

Notation	Variables	Mean	Standard Deviation	Min	Max
P	Production (in Kg)	47814.27	54577.96	2096.76	415129.1
S	Area (in Ha)	2.61	3.04	0.2	18,5
L	Labour (in Working Days)	428.44	364.93	46.5	2950.0
CI	Chemical Inputs (in TD)	1937.83	2491.76	0.00	14000.0
IW	Irrigation Water (in m^3)	97.90	121.83	0.00	900.00
OC	Other Costs (in TD)	631.77	1206.49	0.00	11300.00
AF	Age of Farmer (in years)	55.88	10.64	29.00	80.00
SFL	Share of Family Labour (in %)	0.68	0.36	0.00	1.00
SPT	Share of Productive Trees (in %)	0.86	0.19	0.00	1.00

Note: 1TD =0.65 Euros.
Source: Own elaboration from citrus growing farms in Tunisia.

5. Results and Discussion

5.1. Production Structure

The estimated parameters of the *Cobb-Douglas* stochastic production frontier for the different farms sizes are presented in table 3. From this table it appears that all the parameters (α_i) have the anticipated positive sign and magnitude. On the other hand, the ratio of farm specific to total variability, γ, is positive and statistically significant at the 5% level. The value of 0.81 (for total sample) indicate that output oriented technical efficiency is important in explaining the total variability of output produced. The remaining portion (0.19) is due to factors outside the control of farmer (weather, diseases, etc.). Whereas, output technical efficiency is not important on explaining the volatility of output produced in the case of medium farms (γ is positive but not statistically significant).

Table 3: Parameter estimates (production elasticities) and returns to scale of the frontier model of a sample of Tunisian citrus producing farms.

Parameters	Estimates			
	Small (<1 ha)	Medium (1-2 ha)	Large (>2 ha)	Total Sample
Stochastic Frontier Model				
Intercept	0.72**	0.064	0.64**	0.43**
Ln(S)	0.69**	0.41*	0.22*	0.34**
Ln(L)	-0.054	-0.12	0.42*	0.03
Ln(CI)	0.11*	0.22**	-0.098	0.22**
Ln(IW)	0.37**	0.29**	0.32**	0.33**
Ln(OC)	0.036	-0.02	0.067	0.24
Returns to Scale	**1,152**	**0,78**	**0,929**	**1,16**
Variance Parameter				
σ^2	0.32*	0.16	0.63**	0.38**
γ	0.79**	0.17	0.99**	0.81**
Log-Likelihood	**-15.51**	**-24.96**	**-99.20**	**-79.46**
N	**32**	**58**	**54**	**144**

Notes: **: indicates significance at the 5% level; *: indicates significance at 10% level.

Average estimates of production elasticities and returns to scale for the whole sample and for the different sizes (small, medium and large) are presented in table 3 for the region of study under consideration. For total sample, estimated production elasticities of all five inputs are positives. They indicate that in Nabeul region land is the foremost important input followed by irrigation water and chemical inputs, while labour has the lowest point estimate, which on average were found to 0.03. In economics terms, this latter means that holding all other inputs constant, a 1% reduction in irrigation water requires a sacrifice of 0.33% of marketable output. On the other hand, the hypothesis of constant returns to scale is rejected at the 5% level of significance, and returns to scale were found to be increasing (1.16).

A direct comparison of the parameters estimated (elasticities, in this case) shows the close difference between the small, medium and large farms in terms of intercepts, labour input and returns to scale. Whereas, some similarities are outlined for the importance of water irrigation weight (the relative coefficient is positive and statistically significant for all sizes).

A shadow price of irrigation water may be computed by using the mean values of the relevant variables reported in table 3 and the estimated production elasticity of irrigation water for the whole sample. By combining these figures we find that a reduction of 0.979 m^3 of irrigation water would "cost" approximately 1.24 kilograms in terms of forgone quantities and 0.53 Tunisian Dinars in terms of forgone revenue.

This in turn implies that the shadow price of irrigation water is equal to 0.53 Tunisian Dinars per m^3, a value that is much higher than the market price charged in Nabeul region, which varies 0.09 and 0.1 Tunisian Dinars per m^3. This shadow price should be considered as the upper bound of the true shadow assumption that all other inputs are held constant at their observed levels, which might not be palatable for greater changes in the quantity of irrigation water.

5.2. Technical and Irrigation Water Efficiency

Results for estimates of technical efficiency (TE_i), irrigation efficiency (IE_i), and irrigation water technical cost efficiency ($ITCE_i$) for the whole sample and disaggregated by size of farms are showed in tables 4.

For the whole sample, the estimated mean output-oriented technical efficiency ranges from a minimum of 12.82% to a maximum of 90.69% with an average estimate of 67.73%. This result means that 32.3% increase in production is possible with the present state of technology and unchanged input uses, if technical inefficiency is completely removed. Thus, improving technical efficiency will result to significant increases in framer's revenue and profit.

On the other hand, mean irrigation water efficiency is found to be 53%, which is much lower than technical efficiency and also exhibits greater variability ranging from 1.6% to 98.87%. The estimated mean irrigation water efficiency implies that the observed quantity of marketable citrus could have been maintained by using the observed values of other inputs while using 47.0% less of irrigation water. This means that farmer's can achieve significant savings in water use by improving the utilisation of irrigation system and by utilizing more advanced irrigation technologies. This recommendation is useful for all different farm sizes on which medium farms are expected to be more efficient in this case.

Table 4: Efficiency ratings of Tunisian citrus producing farms.

Efficiency (%)	**IE**	**TE**	**ITCE**
Total Sample (N=144)			
Mean Efficiency	53.00	67.73	70.81
Min. Efficiency	1.6	12.82	70.21
Max. Efficiency	98.87	90.69	99.90
Small Farms (N=32)			
Mean Efficiency	52.06	68.01	91.09
Min. Efficiency	9.41	32.77	75.54
Max. Efficiency	99.05	86.61	99.90
Medium Farms (N=58)			
Mean Efficiency	55.63	70.57	92.86
Min. Efficiency	1.59	12.82	79.17
Max. Efficiency	98.87	90.69	99.85
Large Farms (N=58)			
Mean Efficiency	52.30	64.51	91.37
Min. Efficiency	2.94	29.24	70.21
Max. Efficiency	93.28	90.52	99.59

Source: Own elaboration from citrus growing farms in Tunisia.

Moreover, cost savings that could be attained by adjusting irrigation water to its efficient level, would be small since its outlays constitute a small proportion of total cost. For this reason, the estimated mean $ITCE_t$ is much higher than IE_i for the different sizes. Results from table 4 showed that the estimated mean irrigation water technical cost efficiency is found to be 70.81% (91.01% for small farms; 92.86% for medium farms and 91.37% for large farms) indicating a potential decrease of 29.19% (19%, 7% and 8%, respectively for small, medium and large farms) in total cost by adjusting irrigation water to its efficient level. In addition, the vast majority of farms have achieved irrigation water technical cost efficiency greater than 90% (71% of farms). Thus, even though irrigation water is used least efficiently in technical sense, it offers only few potential cost savings if it is adjusted to its technically efficient level.

5.3. Explaining Efficiency Differentials

The second step of the analysis talks about the sources of efficiency differentials among farmers. In this fact, one of the advantages of Battese and Coelli (1995) model is that allows measurement of technical efficiency (TE) and examination of its differentials among farmers to be done with a single stage estimation procedure. The commonly applied two stage estimation procedure has been recognised as one that is inconsistent with the assumption of identically distributed inefficiency effects in the stochastic frontier, which is necessary in the *maximum likelihood* (ML) estimation (Reifschneider and Stevenson, 1991; Kumhakar *et al.,* 1991; Battese and Coelli, 1995). However, the two stage estimation procedure can be used with no problem for identifying the factors influencing irrigation water efficiency differentials across farms as irrigation efficiency (IE) is calculated from the parameter estimates and the

estimated one sided error component of the stochastic production frontier in (7). The relevant second stage regression model has the following form:

$$\text{Ln } IE_i = h(z_i, \delta) + e_i \qquad (15)$$

Where h (*) is deterministic Kernel of the regression model, δ is the vector of the parameters to be estimated and e_i is an *iid* random variable with zero mean and constant variance. The above model is estimated with standard *OLS*.

Therefore, and in order to explain the sources of efficiency differentials among farmers (small, medium and large), the inefficiency effects model (equation 12) and the second stage regression (equation 15) have been estimated.

Estimation results from theses models are presented in table 5. It is indicated that estimated is carried out only for the whole sample because results by size are, in general terms, not significance.

Table 5: Explaining Efficiency Differentials.

Parameter	**TE**		**IE**	
	Estimate	**Std Error**	**Estimate**	**Std Error**
δ_0	0.911	0.291	1.415	0.5068
δ_{FS}	-0.0079	0.0044	-0.0016	0.0078
δ_{AG}	-0.0073	0.0106	-0.0197	0.0174
δ_{AAGG}	0.000008	0.0000	0.0001	0.00015
δ_{EDC}	-0.0081	0.0334	-0.0177	0.0580
δ_{AT}	-0.012	0.0381	-0.0132	0.0661
δ_{FL}	0.007	0.0422	-0.0184	0.0733
δ_{SPT}	-0.035	0.0673	-0.1351	0.1168
δ_{WDP}	-0.012	0.0295	-0.0154	0.0512
R^2			**0.42**	

Notes: FS: is the farm's size in hectares; AG and AAGG: is the farmer's age and age squared in years; EDC: is the level of schooling (1: illiterate; 2: primary level; 3: secondary level and 4: high school level); AT: is a dummy variable indicating farmer's followed training programs on conducting citrus plantation; FL: proportion of family labour; SPT: share of productive trees measured in % and WDP: is a dummy variable indicating water disposable perception by farmer's.

In the case of the inefficiency effects model, it is important to indicate that a negative sign of the estimated parameter indicates a positive relationship between technical efficiency and the variable under consideration, while in the latter a positive sign depicts a positive relationship between irrigation water efficiency and the corresponding variable.

Farmer's age squared does not seem to affect either technical or irrigation water efficiency. In contrast the farmer's age affect positively technical and irrigation water efficiency. This finding indicates that young farmer's are becoming relatively more technically efficient over time by improving learning by doing. On the other hand, farm's size, education level, agricultural training, the share of productive trees and the water disposable perception tend to affect positively the degree of both technical and irrigation water efficiency. Finally, it is

important to notice that the share of family labour affect positively the efficient use of irrigation water, but negatively the technical efficiency.

5. Concluding Remarks and Policy Implications

The aim of this paper is to measure productive efficiency of irrigation water efficiency based on the concept of technical efficiency and compared among different sizes farms. The proposed methodology is applied to a randomly selected sample of 144 citrus growing farms located in Nabeul (Tunisia) and differentiated by size (small, medium and large farms). A stochastic production frontier approach, based on Battese and Coelli's (1995) inefficiency effect model, is used to obtain farm-specific estimates of technical and irrigation water efficiency. The last step of the analysis consists on the identification of the factors influencing irrigation water efficiency differentials across citrus growing farms on the basis on a second-stage regression approach.

Empirical results show that estimated mean technical efficiency ranges from a minimum of 12.82% to a maximum of 90.69% with an average estimate of 67.73%. This result means that 32.3% increase in production is possible with the present state of technology and unchanged input uses, if technical inefficiency is completely removed. Thus, improving technical efficiency will result to significant increases in framer's revenue and profit.

On the other hand, mean irrigation water efficiency is found to be 53%, which is much lower than technical efficiency and also exhibits greater variability ranging from 1.6% to 98.87%. The estimated mean irrigation water efficiency implies that the observed quantity of marketable citrus could have been maintained by using the observed values of other inputs while using 47.0% less of irrigation water. This means that farmer's can achieve significant savings in water use by improving the utilisation of irrigation system and by utilizing more advanced irrigation technologies.

Moreover, cost savings that could be attained by adjusting irrigation water to its efficient level, would be small since its outlays constitute a small proportion of total cost. For this reason, the estimated mean $ITCE_t$ is much higher than IE_i for the different sizes. Results from table 4 showed that the estimated mean irrigation water technical cost efficiency is found to be 70.81% (91.01% for small farms; 92.86% for medium farms and 91.37% for large farms) indicating a potential decrease of 29.19% (19%, 7% and 8%, respectively for small, medium and large farms) in total cost by adjusting irrigation water to its efficient level. In addition, the vast majority of farms have achieved irrigation water technical cost efficiency greater than 90% (71% of farms). Thus, even though irrigation water is used least efficiently in technical sense, it offers only few potential cost savings if it is adjusted to its technically efficient level.

The analysis of the sources of efficiency differentials among farmers showed that farmer's age affect positively technical and irrigation water efficiency. This finding indicates that young farmer's are becoming relatively more technically efficient over time by improving learning by doing. On the other hand, farm's size, education level, agricultural training, the share of productive trees and the water disposable perception tend to affect positively the degree of both technical and irrigation water efficiency.

Finally, results from this research for small, medium and large farms suggest that a substantial water price increase for citrus farmers would be an appropriate policy for water conservation. In addition, results implies that professional training programs, in advanced irrigation techniques, could be effective, particularly if targeted to farmers with limited skills and

Stimulate the necessity for decisions makers to encourage investment on irrigation equipment machinery by facilitating access to credit. Finally, theses findings could be the background of a new research on providing the sources both of technical inefficiency and productivity growth on the Tunisian citrus producing sector.

References

Aigner D. J, Lovell C. A. K and Schmidt P, 1977. Formulation and estimation of stochastic frontier production function model's. *Journal of Econometrics* 6: 21-37.

Akridge J. T, 1989. Measuring productive efficiency in multiple product agribusiness firms: A dual approch. *American Journal of Agricultural Economics* 71: 116-125.

Atkinson S. E and Cornwell C, 1994. Estimation of output and input technical efficiency using a flexible functional form and panel data. *International Economic Review* 35: 245-255.

Bachata M.S and Ghersi G, 2004. Agriculture et alimentation en méditerranée : Les défis de la mondialisation. KAHRTALA

Battese G. E and Coelli T. J, 1995. A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical Economics* 20: 325–332.

Coelli T. J, 1992. A computer program for frontier production function estimation: Frontier version 2.0. *Economics Letters* 39: 29-32.

Fare R and Lovel C. A. K, 1978. Measuring the technical efficiency of production. *Journal of Economic Theory* 19: 150-162.

Karagiannis G., Tzouvelekas V. and Xepapadeas A, 2003. Measiring irrigation water efficiency with a stochastic production frontier: An application to Greek out-of-season vegetable cultivation. *Environmental and Resource Economics* 26: 57–72.

Kopp R. J, 1981. The measurement of productive efficiency: A reconsideration. *Quarterly Journal of Economics* 96: 477-503.

Kumbhakar S. C and Lovell C. A. K, 2000. Stochastic Frontier Analysis. New York: Cambridge University Press.

Kumbhakar S. C, Ghosh S and McGuckin J. T, 1991. A generalised production frontier approach for estimating determinants of inefficiency in U.S. Dairy farms. *Journal of Business and Economic statistics* 9: 279-286.

Reifschneider D and Stevenson R, 1991. Systematic departures from the frontier: A farmework for the analysis of firm inefficiency. *International Economic review* 32: 715-723.

Reinhard S, Lovell C. A. K and Thijssen G. J, 1999. Econometric estimation of technical and environmental efficiency: An application to dutch dairy farms. *American Journal of Agricultural Economics* 81: 44-60.

Stevenson R. E, 1980. Likelihood functions for generalised stochastic frontier estimation. *Journal of Econometrics* 13: 58-66.