Input, Output Technical Efficiencies and Total Factor Productivity of Cereal Production in Tunisia

Boubaker DHEHIBI[•]

Social, Economic and Policy Research Program (SEPRP)
International Center for Agricultural Research in the Dry Areas (ICARDA)
ICARDA, P.O.Box 5466, Aleppo, Syria
Phone. : +963-212213433 / Fax.: +963-212213490 / 5744622
E-mail: b.dhehibi@cgiar.org

Haithem BAHRI

Laboratory of Rural Engineering Research
National Research Institute in Rural Engineering, Water and Forest (INRGREF)
Rue Hedi Karray, P.O.Box 10
Ariana, 2080, Tunisia
Phone.: +216-71230029 / Fax.: +216-71717951
E-mail. : haithem.bahri@gmail.com

Mohamed ANNABI

Laboratory of Agronomic Sciences and Techniques
National Research Agronomic Institute of Tunisia (INRAT)
Rue Hedi Karray, 2049, Ariana
Phone.: +216-71230024 / Fax.: +216-71752897
E-mail. : mannabi@gmail.com

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[•]Corresponding author: Social, Economic and Policy Research Program (SEPRP). International Center for Agricultural Research in the Dry Areas (ICARDA). ICARDA, P.O.Box 5466, Aleppo, Syria. Phone. : +963-212213433 / Fax.: +963-212213490 / 5744622. E-mail: b.dhehibi@cgiar.org.

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Abstract - In this paper, farm level technical efficiency of production and its determinants are investigated in a sample of 51 cereal producing farms located in the main cereal production region in Tunisia using a stochastic frontier production model.

Empirical findings show that labor input factor appears with a minimal effect on the production. The hypothesis of constant returns to scale is rejected at the 5% level of significance, and returns to scale were found to be decreasing. Moreover, the estimated coefficients in the technical inefficiency model are also as expected. The estimated coefficients of the instruction level of farmer and the rotation, technical variable, are negatives and statistically significant at 5% level, which indicates their positive effect on technical efficiency. In addition, results indicated that estimated technical efficiency of cereal production in the sample varied widely, ranging from 52.63% to 94.62, with a mean value of 77%. This suggests that, on average, cereal producing farmers could increase their production by as much as 23% through more efficient use of production inputs.

On a second step, Timmer and Kopp indexes of technical inefficiency were estimated for the same farms using a Cobb–Douglas frontier production function with a composite error term, and a developed relationship between these two indices. Results show that the mean values of the Timmer and Kopp TE indices were over 0.80, but one half of the farms were below 0.80 for the Timmer index and below 0.83 for the Kopp index. The level of inefficiency was found to be related to farm size: small and large farms were shown to be more technically efficient than medium-sized farms. With the given inputs, the production of cereals could be increased by 20% on average through making all farms 100% efficient. Alternatively, inputs could be reduced by 17% on average to produce the same amount of cereal output. Finally, the lower level of efficiency but higher yield and total factor productivity in the medium-sized farms means that more cereals can potentially be produced in these farms. The findings revealed that significant factors related to TFP were age, education level and the share of wheat crops into total cropped area. These results calls for policies aimed at provision of training programs, extensions services. In addition, the encouragement of experienced farmers by applying improved input management on these farms can be recommended alongside appropriate new technologies, especially for wheat farmers.

Keywords: Technical efficiency; Timmer index; Kopp index; TFP, cereal farms; Tunisia.

J.E.L Classification: C43, O47, Q12.

1. Introduction

The cereal sector in Tunisia plays an important role in agricultural production, employment and agro-food industry. It considers as the dominant agricultural commodity in the Tunisian economy. It represents the main food staple of the Tunisian households. Around 70% and 55% of calories and protein respectively in average diet come from cereals products. In addition, to provide more than half the calories in the average Tunisian diet, they account for about a third of total food expenditures (NSI, 2005).

In recent years, about one third the country's arable land has been devoted to cereal production (1.5 million hectares, and 2 /3 of farms). In 2009/2010, about 60 percent has been in durum wheat, 10 percent in bread wheat, and 30 percent in barley. The sector produced 13% of the total agricultural production with 2.5 million tons in 2009. The average production of the last 10 years is around 1.7 million tons with variation of 0.73 million tons. The fluctuation is attributed mainly to climatic conditions, particularly rainfall, and to inadequate management practices at farm level. However, Cereal productivity in the country remains very low compared to its potential. In fact, the average yield per hectare is below 1.3 ton.

Tunisia once was a net exporter of cereals, particularly of durum. But increased demand caused by rising population and per capita income and stagnating production have turned the country into a net importer of grains. At times during the last three decades, Tunisia filled about half her cereal needs with imports. A continuing rise in demand for human consumption coupled with a developing livestock sector will maintain pressure on cereal output. Some relief is anticipated with in-creasing technological progress in cereal production, particularly in bread wheat.

The food balance was aggravated by the latest increases of world cereal prices. Improvement of cereals' yield in Tunisia became a must for policy makers who seek to reduce the deficit of the food balance. While, the Tunisian government is engaged in an intensive effort to adopt new, high yielding varieties of bread wheat, along with improved cultural practices in wheat production. This effort is designed to increase Tunisian cereal production by improving yields, and to reduce the country's dependence on cereal imports. Important policies were implemented in 2008 to encourage cereal producers. The strategy's goal was to promote the cereal through the extension of cereal areas, introduction of new varieties, price subsidies to production and inputs, etc. The potential at research plots exceed 1.6 kg/m^3 of irrigation water with an average yield per hectare to 6.4 tons while in practice the productivity of irrigated cereals does not exceed 0.9 Kg/m^3.

Since the wheat production is increased, in Tunisia, the concern on efficiency is a major topic of the economics of production on farms on two levels. At the micro level, measuring the efficiency of cereal farms is crucial to better understand the productivity analysis, but also to analyze the effects of regulatory policies markets on farms. At the macro-economic, these individual levels of efficiency determine the social and collective one. Achieving efficiency in the agricultural sector as a whole therefore requires the reversal of the inefficiencies of farms. Studies of the effectiveness production technology are also part of a relevant diagnosis

to identify and understand the main determinants of the effectiveness of production of these structures and suggest alternatives for their improvement adaptation to the regions and farm types.

The objective of this paper is part of this concern and is interested in oriented wheat farms in Tunisia where the cereal is the main agricultural activity. In particular, this research examines the technical efficiency of a sample of cereal producing farms in Tunisia. Second, we analyze the determinants of technical efficiency variation among these farms using a model of simultaneous estimation of the stochastic production and effects of technical inefficiency (Kumbhakar et al,. 1991; Reifschneider and Stevenson, 1991; Huang and Liu, 1994). This approach has a major advantage over the first empirical contributions using a two-step procedure for examine the role of exogenous variables in explaining technical efficiency of production. In addition, the relationship between firm-level output based technical efficiency measure (the Timmer index) and an input based measure (the Kopp index) is developed and theses technical indexes are estimated. The final purpose of this study is the measurement and the analysis of the determinants of Total Factor Productivity (TFP) among the cereals farms. This will further guide policy makers in making policies for the improvement of the welfare of cereal farmers, which will give indicators of their cereal production.

To achieve the mentioned objectives, the remainder of the paper is organized as follows. In section 2, we present the theoretical background of the stochastic frontier model, Timmer and Kopp technical efficiency indices and total factor productivity concept. Section 3 describes the data analysis and the empirical frontier/inefficiency models assumed for the sample of Tunisian cereal producing farms. In the section 4, we present the empirical results and discussions. Finally, the section 5 concludes with some remarks on policy implications.

2. Methodological Framework and Theoretical Background

2.1. Stochastic Production Frontier Estimation

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 et al., (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

[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.

Battese and Coelli (1995) 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 :

$$LnY_i = Lnf(x_i;\beta) + v_i - u_i \quad (1)$$

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

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 modeled as ε_i ~ 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 $(0, \sigma_v^2)$ 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 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,

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

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

2.2. Technical Efficiency: The Timmer & Kopp Indices

In the empirical literature, efficiency can be defined in terms of producing a maximum amount of output, given a set of inputs; or producing a given level of output using a minimum level of inputs; or a mixture of both. Efficient farms either use less input than others to produce a given quantity of output, or for a given set of inputs they generate a greater output.

One of the most popular approaches to measuring technical efficiency is based on the calculation of the output-based Timmer (1971) and the input-based Kopp (1981) indexes of technical efficiency. TE_T is simply the

[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).

ratio of the observed level of output to the potential (frontier) output, given a set of inputs. While, the input-based Kopp (1981) index of efficiency TE_K is defined as the ratio of frontier input (cost) to the observed level of input (cost), given the level of output. According to Llewelyn and Williams (1996), these two indices are not necessarily the same, because input efficiency does not focus on the same aspects of production as those of output efficiency.

According to Fare and Lovell (1978), a unique measure of these two indexes cannot be calculated in the case of non-homothetic technology. Homotheticity, for which homogeneity is sufficient but not necessary (Laidler and Estrin, 1989), implies that all the isoquants have the same slope on a ray through the origin in the input space. These relationships are illustrated using the Cobb–Douglas production function exposed in equation (1). In the mentioned production function, the degree of homogeneity is equal to its sum of the β_i coefficients.

The Timmer index for an individual farm, calculated as the ratio of observed output Y to frontier output Y_f, , for μ =0, is defined as:

$$TE_T = \frac{Y}{Y_f} = \frac{\left(A\prod_{i=1}^{N} X_i^{\beta I} e^{\nu+\mu} \right)}{\left(A\prod_{i=1}^{N} X_i^{\beta I} e^{\nu} \right)} = e^{-\mu} \qquad (7)$$

While the Kopp index can be formulated (for any j) as (Russel and Young, 1983):

$$TE_K = \frac{X_{fj}}{X_j} = \left(e^{-\mu}\right)^{1/\sum \beta_i} = \left(TE_T\right)^{1/\sum \beta_i} \qquad (8)$$

Where X_{fj} and X_j are the frontier and the observed levels of the jth input, respectively (for μ=0).

Timmer and Kopp indices can be calculated directly. The relationship between both indices depends on the returns of scale of the production function (Figure 1). Thus, in the case of constant returns to scale ($\sum \beta_i = 1$), the Kopp index is equal to Timmer index. However, the Kopp index is greater than the Timmer index if $\sum \beta_i > 1$ (which is the case of increasing to scale). Finally, the Kopp index is less than the Timmer index if the production function is decreasing to scale ($\sum \beta_i < 1$).

Given the absence of detailed farm-level data (farmer training programs, extensions, etc.) which may represent the sources of inefficiency, the effect of farm size has been used as a determinant variable of inefficiency cause. This variable is examined by means of a simple quadratic function. The potential efficiency gains, i.e. the rise in the level of output that could be gained (GT =1−TET) or the share of input that could be saved (GK =1−TEK) if the farmer were 100% efficient, may be defined as a function of the input ratios.

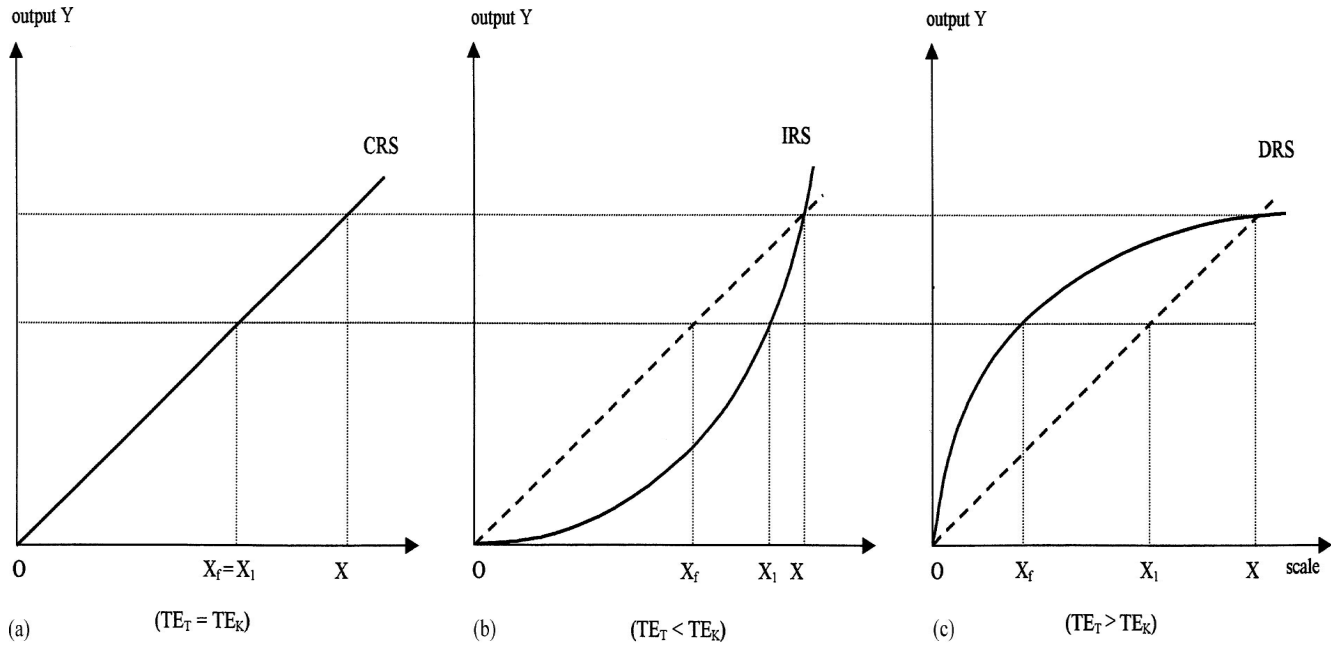

Fig. 1. TE indexes with: (a) constant returns to scale (CRS); (b) increasing returns to scale (IRS) and (c) decreasing returns to scale (DRS).

2.3. Total Factor Productivity

Given the mentioned above, the next step consists on the estimation of the Total Factor Productivity (TFP) and its determinants. Total Factor Productivity as a measure of overall productivity has been gaining recognition and acceptance not only for its theoretical relevance but also for it's practically among farmers and consequently agricultural decisions makers.

In this case, the OLS regression method is used to analyze the effects of various determinants (variables) on TFP of cereal farms. Following Key and Mcbride (2003), TFP can be measured as the inverse of the unit variable cost since the TFP is the ratio of the output and the Total Variable Cost (TVC) as shown in this equation:

$$TFP_i = \frac{Y_i}{\sum_{j=1}^{N} P_{ji} X_{ji}} \quad (9)$$

Where;

Y_i : The output (in value or in quantities);

TVC_i: Total Variable Cost of farm i;

P_{ji}: Unit price of jth variable input used in farm i;

X_{ji}: Quantity of jth variable input used in farm i.

In terms of Total Fixed Cost (TFC), this methodology ignores this component such as does not affect profit maximization and the resource-use efficiency conditions (Bamidele et al., 2008). Then, the TFP for an individual farm can be derived from cost theory as:

$$AVC_i = \frac{Y_i}{TVC_i} \quad (10)$$

Where; AVC_i is the average variable cost measured in Tunisian dinar. Therefore,

$$TFP_i = \frac{Y_i}{TVC_i} = \frac{1}{AVC_i} \quad (11)$$

Thus, TPF_i is the inverse of the average variable cost (AVC_i) of farm i.

3. Data and Empirical Model

3.1. Sources and data analysis

A cross section data of 51 Tunisian cereal producing farms covering the 2008-2009 period are collected from surveys conducted in 5 delegations of the governorate of *Beja*, Tunisia. Cereal 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 the *Beja* region. 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 *Beja* region, taking into account the statistic representation and cultivated areas.

The selected sample comprises 7 farms with a size lower than 2.5 ha (representing 13.7%), 20 farms with a size ranging between 2.5 and 8 ha (39.3%) and 24 farms with a size larger than 8ha (47%). The questionnaire consists of six sections: the first is related to a farmer's socio-economic characteristics. This is comprised of age, education level, agricultural training, experience in the cereal sector, etc. The second section is related to the history of the farm. The third section accounts for the structure of the land (area, repartition of area, number of farms). In the fourth section, we focus on production factors, namely labor (permanent, seasonal, family and its allocation between farm operations), farming operations, material and buildings, and irrigation operations. The intermediate consumption data are collected in section five. Total production data, production by speculation and fixed costs are treated in the last section. The questionnaire results showed that, on average, the age of respondents is 55 years, ranging from 27 to 80. While, the average land holding is 19.55 ha, ranging from 0.5 to 100 ha.

In addition, 55 percent of the sample farmers are illiterate; 23% of completed primary education; whereas 22% accumulated at least 6 years of schooling. Over 80 percent of farmers never followed a training program on conducting cereal farming and improved agronomic techniques. The sample is characterized by a high level of family labor with respect to total labor (45%). Finally, in terms of machinery, only 73% of sampled farmers have tractors. The others, 27%, resort to hiring.

3.2. Empirical Model

To implement the above-specified model, mean cross-section data on 51 Tunisian cereal producing farms in the *Beja* region (Tunisia) covering the year 2008-2009 is used. The choice of this region is justified by its importance

in the national wheat production. Indeed, according to the Ministry of Agricultural and Environment statistics, this region contributed for more then 20% on the national cereal production.

As we posed at the outset, data on output, production inputs (seed, fertilizer, machinery and labor) and other explanatory variables such as the instruction level of farmer, rotation of crops, share of wheat area, the share of family labor and the presence of livestock were chosen for the representation of the underlying *Cobb-Douglass* functional form. The Source of these data is the survey carried out in the *Beja* region, Tunisia. A summary statistics of these variables is provided in table 1.

Table 1. Summary statistics of the variables used in the Frontier Model for cereals producing farms in Tunisia.

Notation	**Variables**	**Mean**	**Standard Deviation**	**Min**	**Max**
Y	Production (in TD)	25448.41	40064.06	287.00	158000.00
A	Land (in Ha)	19.5500	23.84	0.5	100.00
L	Labor (in TD)	1214.41	3899.60	0.00	26550.00
S	Seed (in TD)	1746.02	2163.94	60.00	8160.00
F	Fertilizers (in TD)	2137.10	3182.83	0.00	12750.00
M	Mechanization (in TD)	1384.64	1278.63	139.04	6650.50

Note: 1TD =0.675 US$.
Number of observations: 51.
Source: Own elaboration from cereal producing farms in Tunisia.

Given the above, the stochastic frontier production model to be estimated is defined in equation (12) and the technical inefficiency effects are defined in equation (13) as follows:

$$LnY_i = \beta_0 + \beta_1 LnS_i + \beta_2 LnF_i + \beta_3 LnM_i + \beta_4 LnL + v_i - u_i \quad (12)$$

$$u_i = \delta_0 + \delta_1 (INL)_i + \delta_2 (ROT)_i + \delta_3 (Liv)_i + \delta_4 (FLAB)_i + \delta_5 (SBLE)_i + \varepsilon_i \quad (13)$$

Where:

- Y_i is the value in Tunisian Dinars of the i-th farmer;
- S_i is the value of seeds used in the i-th farmer in Tunisian Dinars;
- F_i is total fertilizers used in the i-th farmer in Tunisian Dinars;
- M_i is the value of machinery used by the i-th farmer in Tunisian Dinars;
- L_i is the value of labor (permanent and occasional) used by the i-th farmer in Tunisian Dinars;
- INL is instruction level dummy variable, (= 1 if the farmer has accumulated at least 6 years of schooling, 0, otherwise);
- ROT is rotation dummy variable, (=1if the farmer has gone through agricultural rotation, 0 otherwise;
- Liv is the livestock dummy variable, (=1 if the farmer have livestock, 0 otherwise);
- FLAB is the share of family labor with respect to total labor;
- SBLE is the percentage of wheat crops within total cereals; and
- v_i and ε_i are random errors.

The maximization of the log-likelihood function is performed by a Newton-Raphson iteration procedure, with the ordinary least squares (OLS) estimates composing the initial estimates of the stochastic frontier production function for the cereals farms.

4. Results and Discussion

The frontier production function

Maximum likelihood estimates of the parameters of the *Cobb-Douglass* stochastic frontier production and the technical inefficiency effects models are obtained using the computer package FRONTIER version 4.1 (Coelli, 1996). The estimate for the variance parameter γ significantly different from zero implies that the inefficiency effects are significant in determining the level and the variability of the cereal producing farms.

Parameters estimates, along with the standard errors and T-ratios of the ML estimators of the Tunisian cereal producing farms inefficiency frontier model are presented in table 2. The signs of the estimated parameters of the *Cobb-Douglass* stochastic frontier production model are as expected. All estimated coefficients of inputs are positive and significant, which confirms the expected positive relationship between seed, fertilizers, machinery and labor and cereal production.

Average estimates of productions elasticities and returns to scale are also presented in table 2. Estimated partial production elasticities with respect to these production factors indicated that seed impact factor is greater than other intermediate inputs factors such as fertilizers, machinery and labor. The value of these elasticities for seed, fertilizer, machinery and labor are 0.78, 0.07, 0.10 and 0.032, respectively.

These results reflect the economic reality of cereal producing farms in the region, subject of study. Indeed, cereal production is principally related with machinery and seed. The labor input factor appears with a minimal effect on the production since all of the operations in cereal producing farms are mechanized. In economics terms, this latter means that holding all other inputs constant, a 1% reduction in labor requires a sacrifice of 0.032 % 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 decreasing (0.983).

The estimated coefficients in the technical inefficiency model are also as expected. The estimated coefficient of the instruction level of farmer (NIN) is negative and statistically significant at 5% level, which indicates their positive effect on technical efficiency. With respect to the rotation (ROT), technical variable of particular interest to farmers is negative and significant. Consequently, the negative and statistically significant at the 5% level coefficient suggests that an increase in the area of wheat contributes to higher technical efficiency levels of cereal production on these farms. Finally, the estimated coefficient of the share of family labor (FLAB) and the presence of livestock (ELE) in the technical inefficiency model are positive and statistically insignificant at 10%. This implies their neutral effect on technical efficiency.

Table 2. Parameter estimates and t-values of the inefficiency frontier model of a sample of Tunisian cereal producing farms.

Variables	Estimates	t-values
Stochastic frontier model		
Intercept	0.157	2.320*
Ln (Seed)	0.780	2.773*
Ln (Fertilizer)	0.069	2.544*
Ln (Machinery)	0.102	11.39*
Ln (Labor)	0.032	1.526**
Partial production elasticity		
$E_{Y/S}$	0.780	-
$E_{Y/F}$	0.069	-
$E_{Y/M}$	0.102	-
$E_{Y/LA}$	0.032	-
Returns to scale	0.983	
Inefficiency effects model		
Intercept	0.272	2.411*
NIN	-0.147	-2.968*
ROT	-0.184	-1.723**
ELE	0.055	0.954
FLAB	0.073	1.00
SBLE	-0.215	-1.898**
Variance parameters		
σ^2	0.030	3.393*
γ	0.89	5.862*
Log-likelihood	29.790	

Source: Own elaboration from cereal producing farms in Tunisia.
Note: **. Significant at the 10% level. *. Significant at the 5% level.

Frequency distribution results of technical efficiency are presented in table 3. Estimated efficiency measures reveal the existence of substantial technical inefficiencies of production in the sample of cereal producing farms at hand.

Table 3. Efficiency ratings and frequency distribution of Tunisian cereal producing farms.

Technical Efficiency (%)	Number of farms	% of farms
TE $\leq$ 60	4	7.8
60 < TE $\leq$ 70	11	21.6
70 < TE $\leq$ 80	16	31.4
TE > 80	20	39.2
Mean Efficiency	76.93	
Min.	52.63	
Max.	94.62	

Source: Own elaboration from cereal producing farms in Tunisia.

The computed average technical efficiency is 76.93% ranging from a minimum of 52.63% to a maximum of 94.62%. Given the present state of technology and input levels, this suggests that firms in the sample are producing on average at 77% of their potential. Within this framework, 20 firms are relatively more efficient than the sample average efficiency level, with an efficiency score greater than 80% and 31 firms show value of

mean efficiency less than average one. These results make inquiries about heterogeneity and the possibility that these producing farms can increase their production by 13% given the present state of technology and inputs level.

The Timmer and Kopp technical efficiency indices

The next step of results consists on the analysis of the *Timmer* and *Kopp* technical efficiency indices. Using the values of μ_j , equation (7) was estimated for individual farms as a basis for the TE_T and TE_K inefficiency indices, whose frequency distributions are shown in Table 4.

The mean value of TE_T is estimated to be 0.80, with range from 0.54 to 0.98, while the average TE_K is found to be 0.83 (range 0.58–0.97). The mean values indicate that either output can be increased on average by 20% with the same amount of inputs as before, or the current level of output can be produced using 17% less inputs on average than are applied by farmers. About 22 farms of the observations were under 80% efficient for the TE_T and under 90% efficient for the TE_K. At least one cereal producer could gain over 20% by input reallocation or over 10% by output maximization.

The frequency of the Timmer and Kopp indexes among the farms indicates that 12 farms (23.5%) had an output-based efficiency level of 0.90 or above and 17 farms (33.5%) an input-based efficiency in that range. About 2% of farms were in an input-based inefficiency range below 0.50 and 4% of farms were in an output-based inefficiency range also below this percentage. In summary, most farms are recognized to be more than 80% efficient on both measures, but there is over 27% of farms inefficient on either measure.

Table 4. Frequency distribution of Timmer and Kopp indices.

Efficiency index		**Frequency**		**Percentage**		**Cumulative frequency**		**Cumulative percentage**	
TE_T	TE_K	TE_T	TE_K	TE_T	TE_K	TE_T	TE_K	TE_T	TE_K
[0.5 0.6)		2	1	3.92	1.96	2	1	3.92	1.96
(0.6 0.7)		9	5	17.65	9.80	11	6	21.57	11.76
(0.7 0.8)		11	11	21.57	21.57	22	17	43.14	33.33
(0.8 0.9)		17	17	33.33	33.33	39	34	76.47	66.67
(0.9 1]		12	17	23.53	33.33	51	51	100.00	100.00

Summary statistics of Timmer and Kopp Technical Efficiencies Indices

	TE_T	TE_K	G_T	G_K
Mean	0.80	0.83	0.192	0.162
Standard - Dev	0.11	0.10	0.11	0.10
Minimum	0.54	0.58	0.018	0.023
Maximum	0.98	0.97	0.45	0.42

Source: Own elaboration from cereal producing farms in Tunisia.

Causes of inefficiency

As expressed in data source section, quantitative farm-level data on the sources of inefficiency are not available for Tunisian cereal farmers, although it may be conjectured that these sources include the difficulty of acquiring inputs such as chemical and organic fertilizers. In the absence of such evidence, farm size, and input ratios, which differ from large to small farms, are considered as determinants of the potential efficiency gains G_T and G_K (Bakhshoodeh and Thomson, 2001). The relation between both TE indices and farm size (as measured by land area, L_1) was examined by an estimated quadratic equation (standard errors of coefficients in parentheses).

$$G_T = 0.202\,(0.022) - 0.0000016\,(0.002) * L_1 - 0.000001\,(0.00005) * L_1^2 \quad (9)$$

$$G_k = 0.165\,(0.022) + 0.000492\,(0.0019) * L_1 - 0.0000013\,(0.0000238) * L_1^2 \quad (10)$$

The signs of estimated coefficients suggest the potential efficiency gains G_T and G_K increase up to a certain point (around 8 ha) and decrease again with larger farm sizes. Therefore, in terms of general objective of attaining self-sufficiency in agricultural products and raising the level of cereal production, policies for improving efficiency should be directed towards the medium-sized farms. The average yield of cereal crops in these farms (20.61 Qx/ha) is higher than that of large and small farms (15.47 Qx/ha), and their lower level of efficiency implies a higher potential output. A comparison of mean efficiency gains among the farms with different sizes shows that the efficiency gain for the medium-sized farms (2.5 – 8 ha) is significantly higher than that for very small farms. Such differences could be due to the technologies applied at different sizes, and to the economies of scope related to the degree of on-farm diversification.

Table 5. Mean efficiency gains G_T and G_K by farm size.

Farms	**Size (ha)**	**Number of farms**	**G_T**	**G_K**
Large	> 8	24	0.184 (0.116)	0.160 (0.108)
Medium	5 – 8	6	0.203 (0.109)	0.169 (0.107)
Small	2.5 – 5	14	0.203 (0.111)	0.166 (0.108)
Very small	< 2.5	7	0.184 (0.184)	0.153 (0.153)

Note: Standard errors are in parentheses.
Source: Own elaboration from cereal producing farms in Tunisia.

Total factor productivity and its determinants

The last section of the paper focuses on the analysis of the economic determinants of total factor productivity (TFP) among cereal farmers in Tunisia. Results of such analysis are presented in table 6.

Table 6. *Cobb-Douglass* estimates of the OLS regression of the determinants of Total Factor Productivity (TFP) among cereal farmers in Tunisia.

Variables	**Estimated coefficients**	**Standard error**	**t-Student**
Dependent variable: TFP			
Intercept	0.714	0.082	8.64
Age	0.298	0.134	2.21
Age^2	-0.0024	0.0012	-2.01
Education level	1.28	0.52	2.45
Rotation	0.074	0.473	1.56
% cropped wheat area	0.063	0.013	2.79
N	51		
R^2	0.54		
F- statistics	2.93		

Source: Own elaboration from cereal producing farms in Tunisia.

The coefficients for age, education level and the share of wheat crops into total cropped area were positive and highly significant at 5% level. This implies that 1% increase in age, education level and share of cropped wheat area will increase TFP productivity by 0.29, 1.28 and 0.063%, respectively. In addition, rotation agronomic technique was positive and only significant at 1% level. This is expected and implies the importance of this variable on improving TFP of cereal farms. The adjustment coefficient (R2) value is around 55%, which implies that 55% of the variations in total factor productivity of cereal farms in Tunisia were explained by the included variables. Te F-ratio was significant at 1% which implies that data attests to the overall significant of the regression equation.

5. Concluding remarks and policies implications

In this paper, farm level technical efficiency of production and its determinants are investigated in a sample of 51 cereal producing farms located in the main cereal production region in Tunisia using a stochastic frontier production model. The data used in this study were gathered through a survey carried out during the periods 2008-2009.

Empirical findings show that labor input factor appears with a minimal effect on the production. In economics terms, this latter means that holding all other inputs constant, a 1% reduction in labor requires a sacrifice of 0.032 % 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 decreasing (0.983). Moreover, the estimated coefficients in the technical inefficiency model are also as expected. The estimated coefficient of the instruction level of farmer is negative and statistically significant at 5% level, which indicates their positive effect on technical efficiency. With respect to the rotation, technical variable of particular interest to farmers is negative and significant. This highlights the need for government policies, through extension activities, to set

up training programs on conducting cereal plantation, in general, and improving rotation techniques, in particular.

Consequently, the negative and statistically significant at the 5% level coefficient suggests that an increase in the area of wheat contributes to higher technical efficiency levels of cereal production on these farms. Farmers can improve the level of inefficiency either by applying a new technique of production that is a different combination of inputs, or by adopting technological progress. They may accept more easily and quickly a new combination of inputs to reduce the total cost of production, i.e. to increase the profit per ha, than a new technology. So, encouraging more efficient techniques can be regarded as a policy with relatively speedy effects to increase the profitability of wheat production, and to release surplus inputs to be used in the production of an extra amount of either wheat or other products.

Empirical findings show that estimated technical efficiency of cereal production in the sample varied widely, ranging from 52.63% to 94.62, with a mean value of 77%. This suggests that, on average, cereal producing farmers could increase their production by as much as 23% through more efficient use of production inputs. This result implies that improvement of technical efficiency should be the first logical step for considerably increasing cereal production in the study region.

On other hand, Timmer and Kopp indexes of technical inefficiency were estimated for the same farms using a Cobb–Douglas frontier production function with a composite error term, and a developed relationship between these two indices. The results show that the mean values of the Timmer and Kopp TE indices were over 0.80, but one half of the farms were below 0.80 for the Timmer index and below 0.83 for the Kopp index. The level of inefficiency was found to be related to farm size: small and large farms were shown to be more technically efficient than medium-sized farms. With the given inputs, the production of cereals could be increased by 20% on average through making all farms 100% efficient. Alternatively, inputs could be reduced by 17% on average to produce the same amount of cereal output. The lower level of efficiency but higher yield and total factor productivity in the medium-sized farms means that more cereals can potentially be produced in these farms. The findings revealed that significant factors related to TFP were age, education level and the share of wheat crops into total cropped area. These results calls for policies aimed at provision of training programs, extensions services. In addition, the encouragement of experienced farmers by applying improved input management on these farms can be recommended alongside appropriate new technologies, especially for wheat farmers.

This fact means that the problems of cereal sector is not merely a result of the shortages in production inputs but inefficient use of inputs and their improper combinations are among the most fundamental problems of the cereal production sector. Regarding theses findings, it can be concluded that optimum use of existing inputs and improved combination of them should be emphasized rather than increasing the amount of inputs.

Finally, studying the sources of inefficiency such as diversification versus specialization, and availability and suitability of new technologies, and to determine the level of other indices of inefficiency such as profit efficiency, are recommended in order to develop more productive and profitable techniques of cereal production in Tunisia.

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