Efficiency of wheat production in Egypt

YAHIA HAMID ELASRAAG AND SILVERIO ALARCÓN

Jel codes: C23, O13, Q10

Abstract

This study was carried out to estimate the technical efficiency of the main governorates of wheat production in Egypt during the time period 1990-2012. We apply the stochastic frontier approach for efficiency measurement. The specifications of Battese and Coelli (1992) and (1995) are employed. The results indicate that the levels of technical efficiency vary among the different governorates of wheat production in Egypt.

Key words: *wheat sector, stochastic model, efficiency.*

Résumé

L'objectif de cette étude est l'estimation de l'efficacité technique des principaux gouvernorats de production de blé en Egypte pendant la période 1990-2012. Nous appliquons l'approche de frontière stochastique pour la mesure de l'efficacité. Les spécifications de Battese et Coelli (1992) et (1995) sont employées. Les résultats indiquent que les niveaux d'efficacité technique varient selon les différents gouvernorats de production de blé en Egypte.

Mots clés: secteur du blé, modèle stochastique, efficacité.

1. Introduction

Egypt occupies the north-east corner of Africa and lies between latitudes 22°N and 32°N and longitudes 25°E and 36°E. Most of the country has a hot sub-tropical desert climate. Winters are without frost, but sufficiently cool for wheat. Rainfall is negligible. No crop can be grown in this climate without irrigation. The mean daily temperature during the wheat growing period ranges from 15.7°C to 21.4°C. In Egypt wheat is the most important winter crop grown. It is produced widely in both the older farming lands of the Delta and in the newly-farmed lands reclaimed from the desert. For over 97% of the total wheat crop, the soft varieties dominate domestic production. The exception to this is found in the southern governorates of Assuit, Menia, and Suhag, where some hard to extra-hard types (durum) of wheat are grown (Tyner *et al*., 1999).

Total planted area grew due mainly to an increase in government procurement prices, the improved profitability of wheat-based rotation, the implementation of more productive cultural practices, and more liberal policy environment, which allowed farmers to base their crop planting decisions on market forces and provided them with an incentive to adopt modern technology. All these factors reinforced each other in making investment in wheat production a more attractive and lucrative enterprise (USDA, 1997; Kherallah *et al*., 2000). The vast majority of Egyptian wheat farms are small, irrigated, and owner-operated. Irrigation is almost universal in Egyptian agriculture, allowing the cultivation of summer and winter crops. In the frontier, irrigation water comes from wells. Wheat plays an important role in farmers' crop rotations. The most common winter-summer rotations are wheat-rice, clover-cotton, wheat-maize, and clover-maize (Kherallah *et al*., 2000).

Egypt has one of the largest per capita consumption levels of wheat in the world, and it is one of the world's largest importers of wheat. Two major factors are seriously increasing the rate of change in domestic wheat consumption; the rate of population growth and the rate of growth in wheat consumption per capita. These two factors are, consequently, affected by numerous other factors such as the adopted economic policies, income and its distribution among individuals, and the rate of change in prices (Tyner *et al*., 1999). The Government of Egypt (GOE) does continue to intervene in several markets, including the wheat market. At the same time policy makers try to look ahead to design new policies which aim to achieve greater food security. On the supply side, GOE policy is to achieve the highest possible self-sufficiency in wheat, basically to avoid international risks in wheat markets. Government procurement is typically at prices that are mostly higher than world equivalent prices. A further important contributing factor was raising yields after 1986 due to the diffusion of high-yielding long-spike varieties. Government intervention aimed at increasing self-sufficiency in wheat, thus reducing dependency on imports through support prices provided to wheat farmers and expansion of wheat area (Croppenstedt *et al*., 2006).

The technical efficiency of wheat production in Egypt is a very important indicator because it provides more precise information about what happens in the production process.

[1] Department of Agricultural Economics, Faculty of Agriculture, Cairo University, Giza, 12613, Egypt. Corresponding Author E-Mail: yahiah7@agr.cu.edu.eg

[2] Department of Agricultural Economics, Statistics and Business Management, Technical University of Madrid, Ciudad Universitaria s/n, 28040 Madrid, Spain.

The objective of this study is to examine the input-output relationship of wheat production and estimate the technical efficiency of the main governorates of wheat production in Egypt during the time period 1990-2012.

The paper is organized as follows: the next section presents the literature review; Section 3 contains the methodology; Section 4 explains the empirical model. Section 5 describes the data; Section 6 indicates the results, and the final section presents the conclusions.

2. Literature Review

Two approaches can be applied to estimate the technical efficiency, the Stochastic Frontier Analysis (SFA), which is parametric and Data Envelopment Analysis (DEA), which is nonparametric. Bravo-Ureta and Pinheiro (1993) examined a total of 30 studies from 14 different countries and indicated that considerable effort has been devoted to measuring efficiency in developing country agriculture using a wide range of frontier models. An important issue that concerns the stochastic frontier models is the distributional assumptions made for the one-sided error. SFA has some advantages over DEA, which are: it accounts for noise and it can be used to conduct conventional tests of hypotheses; while some disadvantages of SFA over DEA are: The need to specify a distributional form for the inefficiency term and the need to specify a functional form for the production function or cost function, etc. (Coelli *et al*., 2005). The two alternative approaches have different strengths and weaknesses (Hossain et al., 2012) but the gap between them has been narrowed in recent years with the progress of knowledge in this field (Fried et al., 2008). The main advantages of DEA are its computational simplicity and DEA-based estimate not requiring any information more than output and input quantities. However DEA is sensitive to measurement errors or other noise in the data because DEA is deterministic and attributes all deviations from the frontier to inefficiencies. The main advantages of SFA are that it considers stochastic noise in data and also allows for the statistical testing of hypothesis concerning production structure and degree of inefficiency. The main weaknesses are that it requires an explicit imposition of a particular parametric functional form representing the underlying technology and also an explicit distributional assumption for the inefficiency terms. However, from the most recent works in the agricultural field we can observe an increasing use of SFA. The reason is that most of the initial disadvantages of SFA have been overcome (Headey *et al*., 2010). The prior specification of the functional form is no longer a major issue as a number of flexible forms, such as the translog, provides suitable second-order approximations. Another potentially restrictive feature is that SFA can only handle single-output and multiple-input production processes, but this is no longer a critical constraint because of techniques that designed to directly estimate the input and output distance functions. These distance functions by definition are very general and provide a stochastic alternative to their computation using DEA (Coelli and Perelman, 2000; O'Donnell and Coelli, 2005; Silva., 2004). Moreover, these distance functions can be estimated using standard software like FRONTIER program (Coelli., 2005), so computational complexity is no longer an issue. In addition that SFA has overcome some of the initial disadvantage, from the empirical point of view it is highlighted that the most important potential advantage of SFA is that it can separate noise in the data from genuine variations in efficiency, whereas DEA attributes all measurement errors or omitted variable effects to inefficiency. This can lead to DEA results are difficult to interpret. Furthermore, with SFA the variability in production data is captured in standard errors around the estimated efficiency scores, allowing saying something about confidence intervals (Headey., 2010).

There have been many applications of frontier production functions to agricultural production over the years. Battese and Coelli (1995) applied the stochastic frontier production function (Cobb-Douglas form) for panel data of paddy farmers from the Indian village of Aurepalle. These data were collected by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) from 1975-76 to 1984-85. The output was the total value of output, while the inputs were land, the proportion of the operated land that was irrigated, labor, bullock labor, costs (refers to the value of fertilizer, manure, pesticides, machinery, etc.), age, and schooling. The results indicated that the model for the technical inefficiency effects, involving a constant term, age and schooling of farmers and year of observation, was a significant component in the stochastic frontier production function. The application also illustrated that the model specification permits the estimation of both technical change and time-varying technical inefficiency, given that inefficiency effects were stochastic and had a known distribution.

Coelli and Battese (1996) applied the stochastic frontier production function model (Cobb-Douglas form), and used the specification of Battese and Coelli (1995) on the three villages of Aurepalle, Kanzara and Shirapur, which were selected by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) for the in-depth study of the farming operations involved because they were considered broadly representative of the semi-arid tropics of India. The numbers of farmers involved in survey at the three villages are 34, 33 and 35 for Aurepalle, Kanzara and Shirapur, respectively. The output was the total value of output from the crops which were grown, while the inputs were land, labor, bullock labor, cost of other inputs, age of farmer, and schooling of farmer. The results indicated that the efficiencies differ substantially within each village. They ranged from quite small values of less than 0.1 to values in excess of 0.9. The mean efficiencies of the farmers in the three villages did not appear to differ substantially. They were 0.747 for Aurepalle, 0.738 for Kanzara and 0.71 1 for Shirapur.

Goyal and Suhag (2003) examined the technical efficiency of wheat farmers in Haryana state of India. They estimated a stochastic frontier production function of Cobb-Douglas form for three years from 1996-97 to 1998-99, and they used the specification of Battese and Coelli (1992). The farm level panel data was collected from 200 farmers spread over in each year. The output was the quantity of wheat while the inputs were human labor, quantity of fertilizer, irrigation expenditure, value of seeds, land area, and capital expenditure. Results indicated that technical efficiencies were time varying and declined over time. The mean technical efficiency declined from 0.92 in the first year to 0.90 in the third year.

Hassan and Ahmad (2005) estimated the technical efficiency of wheat farmers in the mixed farming system of the Punjab, Pakistan, by using stochastic frontier production function, incorporating technical inefficiency effect model. The study used the primary data which were collected from 112 wheat farmers. The Cobb Douglas production function was found to be an adequate representation of the data, and they implemented the specification of Battese and Coelli (1995). The mean technical efficiency of wheat farmers was 0.936 ranging between 0.58 and 0.985. The results of frontier model indicated that wheat production could be increased by increasing wheat area, weedicide, cultivations and fertilizer use. The results of the inefficiency effect model indicated that the technical inefficiency could be reduced by sowing the crop in time, increasing education of the farmers, providing credit to the farmers and sowing the crop by drill method. The shortage of the canal water on the other hand increased the inefficiency of the wheat farmers in the mixed farming system of the Punjab. The individual impacts of some variables in the inefficiency effect model were non-significant, but the combined influence of all the variables (wheat area, irrigation, weedicide, cultivation, fertilizer, manure, family labor, and seeds) was significant in reducing the inefficiency of the wheat farmers in the mixed farming system of the Punjab.

Covaci and Sojková (2006) explained the technical efficiency among farms in Slovakia. The data employed for the stochastic frontier model (translog functional form) are taken from a sample of farm data obtained from the Research Institute of Agricultural Economics and Nutrition in Bratislava (VÚEPP) from 2000-2004. Two stochastic frontier model specifications were employed, the Battese and Coelli (1992), and the Battese and Coelli (1995). The output was the wheat production and the inputs comprised seed, fertilizers, chemicals, and land. Technical efficiencies of wheat production were 0.7587, 0.9086, 0.7764, 0.6141, and 0.8655 respectively for the period from 2000 to 2004.

Kachrooa et al. (2010) estimated the technical efficiency of wheat farmers under dryland and irrigated conditions in the Jammu district of Jammu and Kashmir state, India for the year 2006 in a Cobb-Douglas production function, and they applied the specification of Battese and Coelli (1992). The information was collected by interviewing the farmers personally and the farmers were selected by simple random sampling to constitute the sample of 200 farmers from the whole area under study. The output was the quantity of wheat yield and the inputs were wheat area, quantity of seeds, quantity of fertilizers, and labor. The stochastic frontier production function has been used to estimate the technical efficiency of these farmers. The estimated mean technical efficiency of wheat farmers under dry condition has been found to be 0.84, indicating 84 percent efficiency in their use of production inputs, and for irrigated condition it has been found to be 0.88, that means the average output of wheat could be increased by 12 percent by adopting technology properly.

Kaur (2010) analyzed the technical efficiency in wheat production across different regions of the Punjab state, India. It is based on the cross sectional data collected from a random sample of 564 farm households comprising 58, 318, and 188 households from semi-hilly, central and south-western regions for the year 2005-06. The study implemented the stochastic frontier production approach, in the Cobb-Douglas production function, and they used the specification of Battese and Coelli (1992). The output was the quantity of wheat and the inputs were wheat area, expenditure on plant protection chemicals, irrigation, human labor, machine labor, quantity of chemical fertilizer, and regional dummies. The mean technical efficiency of wheat production has been found 87 percent, 94 percent, 86 percent and 87 percent in semi-hilly, central, south-western and Punjab state as a whole, respectively. The results signified that farmers of the central region do not have much scope to increase productivity of wheat through technical efficiency improvement under the existing conditions of input-use and technology. In the semi-hilly and south-western regions, the yield of wheat can be improved to the extent of 13 percent and 14 percent, respectively through adoption of better practices of technology.

Reddy (2012) applied the stochastic frontier production function (Cobb-Douglas form) for panel data on districts at Orissa state in India. The author used the specification of Battese and Coelli (1995). The database of the International Crops Research Institute for Semi-arid Tropics (I-CRISAT) district level from 1971 to 2008 is used for the study. The whole study period from 1971 to 2008 is divided into two periods (period-I: 1971-1990 representing pre-liberalization of Indian economy; period-II: 1991-2008 representing post-liberalization). The analysis is done for the old undivided 13 districts. The output was the Gross Value of Agricultural Production (GVAP), while the inputs were gross cropped area, gross irrigated area, rural agricultural workers, total adult male buffalo and cattle population, number of tractors, quantity of fertilizer, area under high yield varieties, and time variable. The variables which may influence the efficiency of a district are loans, rainfall, rural literates, length of roads, pulses area, oilseeds area, high value crops (HVCs) area (sugarcane, cotton, fruits, vegetables and spices), central table land dummy, eastern Ghat dummy, and coastal plain dummy. The results revealed that the Gross Cropped Area (GCA), cattle population and number of rural agricultural workers have positive and significant influence on district level GVAP. Time is not significant, which infer that there is no significant technological progress during the past 37 years. Inefficiency of district crop production is negatively affected by rainfall, number of rural literates, and area under pulses, oilseeds and HVCs.

We did not find sufficient empirical works that estimate the technical efficiency of wheat production on the level of governorates in Egypt. Therefore, from this perspective this is a novel work. From the point of view of establishing an agricultural policy for Egypt, the contributions of this work are important because it provides recommendations for improvement.

3. Methodology

Technical efficiency (TE) represents the capacity and willingness of an economic unit to produce the maximum attainable output from a given set of inputs and technology (Koopmans, 1951). Technical efficiency can be estimated by employing different approaches and these include stochastic production frontier (parametric approach) and data envelopment analysis (nonparametric approach). Data envelopment analysis works under the assumption of no random shocks in the data set. Farmers always operate under uncertainty and therefore, the present study employs a stochastic production frontier approach introduced by Aigner *et al.* (1977); and Meeusen and Broeck (1977). Following their specification, the stochastic production frontier can be written as:

$$y_{it} = f(x_{it}, t; \beta) e^{\varepsilon_{it}}$$

where y_{it} is the output of the *i*-th firm ($i = 1, 2\ldots,N$) in period $t = 1,2\ldots,T$; x_{it} is a vector of inputs quantities of *i-th* firm in period *t*; t is the time variable; β is a vector of unknown parameters to be estimated; and ε_{it} is an error term. The stochastic production frontier is also called composed error model, because it postulates that the error term ε_{it} is decomposed into two components: stochastic random error component (random shocks) and technical inefficiency component as follows:

$$\varepsilon_{it} = v_{it} - u_{it}$$

where v_{it} is a symmetrical two sided normally distributed random error that captures the stochastic effects outside the firm's control, measurement errors, and other statistical noise. It is assumed to be independently and identically distributed iid $N(0, \sigma^2_v)$. u_{it} is a vector of independently distributed and non-negative random disturbances that are associated with output-oriented technical inefficiency. Specifically, u_{it} measures the extent to which actual production falls short of maximum attainable output. The Battese and Coelli (1992) stochastic frontier production model for panel data where technological inefficiencies of firms may vary systematically over time, this model defines inefficiency coefficients as an exponential function of time (Coelli., 2005). In the model specification of Battese and Coelli (1995), technical inefficiency effects are explicitly expressed as a function of a vector of firm-specific variables and random error, and are integrated in the stochastic frontier model. This one-stage model is recognized as one which provides more efficient estimates than those which could be obtained using the two-stage estimation procedure. Another reason for estimating all parameters in one stage is that, in general, it is hard to distinguish between a variable that belongs to the production function and explanatory variables of the inefficiency model. In the one-stage model, explanatory variables directly influence the transformation of inputs and efficiency is estimated, controlling the influence of explanatory variables of technological inefficiency. This reduces the omitted variable problem in the two-stage estimation.

4. Empirical Model

The translogarithmic function and the Cobb-Douglas functional form are the two most common functional forms which have been used not only in empirical studies on frontier production, but in the studies on production behavior in general. The Cobb-Douglas production function is an adequate representation of our data. The Cobb-Douglas production function can be defined as:

$$\ln y_{it} = \beta_0 + \sum_{j=1}^{3} \beta_j \ln x_{jit} + \beta_t t + v_{it} - u_{it} \quad (1)$$

where y_{it} is the wheat production of the *i-th* governorate at the *t-th* time period; x_{jit} is the *j-th* input of the *i-th* governorate at *t-th* time period; β is unknown parameter to be estimated; *t* is the time variable; v_{it} is a vector of random errors that are assumed to be independently and identically distributed iid $N(0,\sigma^2_v)$; and u^{it} is a one sided ($u_{it} \geq 0$) efficiency component that captures the technical inefficiency of the *i-th* governorate. The two error components (v_{it} and u_{it}) are independent of each other.

As defined by Battese and Coelli (1992), the non-negative inefficiency effect is an exponential function of time. Considering the condition of the analyzed time period, the systemically time-varying inefficiency model can be written into an equation:

$$u_{it} = u_i \exp(-\eta(t-T)) \quad (2)$$

where the distribution of u_i is taken to be the non-negative truncation of the normal distribution $N(\mu,\sigma^2_v)$ and η is a parameter that represents the rate of change in technical inefficiency. A positive value ($\eta > 0$ is associated with the improvement of governorate' technical efficiency over time.

The inefficiency effect model defined by Battese and Coelli (1995) is specified as follows:

$$u_{it} = \delta_0 + \sum_{j=1}^{4} \delta_j Z_{jit} \quad (3)$$

where u_{it} is the technical inefficiency of the *i-th* governorate at *t-th* time period; δ is a vector of parameters to be estimated; and Z_{jit} is a vector of variables which expected to influence the level of technical inefficiency of the *i-th* governorate at *t-th* time period. In this study we have two dummy variables to indicate whether the governorate is located in Upper Egypt or in Lower Egypt; Z_1 equal to 1 if the governorate lies in Upper Egypt and zero otherwise, Z_2 equal to 1 if the governorate lies in Lower Egypt and zero otherwise. Additionally, we incorporate the time variable (Z_3) to verify if the technical inefficiency increase or decrease in the analyzed period. We also have one dummy variable (Z_4) to represent the gender; Z_4 equal to 1 if the percentage of males more than the percentage of females at *i-th* governorate at *t-th* time period and zero otherwise. Thus, this model accounts for technical change, through the time variable *t*, and for changes of the technical efficiency over time, by means of the variable (Battese and Coelli, 1995).

The Maximum Likelihood estimates for the parameters of the stochastic frontier model, defined by equations (1), (2) and (3) can be obtained by using the FRONTIER 4.1 program, in which the variance parameters are expressed in terms of (Coelli, 1996):

$$\sigma_s^2 = \sigma_u^2 + \sigma_v^2 \; ; \gamma = \frac{\sigma_u^2}{\sigma_s^2} \; and \; 0 \le \gamma \le 1 \; .$$

The technical efficiency level of the *i-th* governorate at the *t-th* time period is defined as the ratio of the actual output to the maximum potential output as follows:

$$TE_{it} = \exp(-u_{it}) .$$

5. Data

Table 1 shows the wheat production, area, and yield of the main governorates in Egypt. The wheat production increased from 327.34 thousand ton in 1990 to 631.10 thousand ton in 2012. The annual average percentage growth rate of wheat production for the time period 1990-2012 was 3.03%. The wheat area increased from 58.49 thousand hectare in 1990 to 93.52 thousand hectare in 2012. The annual average percentage growth rate of wheat area for the time period 1990-2012 was 2.16%. The wheat yield increased from 5.60 ton/hectare in 1990 to 6.75 ton/hectare in 2012. The annual average percentage growth rate of wheat yield for the time period 1990-2012 was 0.85%.

Table 2 shows the main governorates of wheat production in Egypt. During the time period 1990-2012 there was an increasing in the wheat production, area, and yield at the main governorates. The annual average percentage growth rates for the time period 1990-2012 indicate increasing in wheat production, area, and yield of the main governorates. During the time period 1990-2012, Behairah governorate had the highest annual average percentage growth rate of wheat production

Table 1 - *Wheat production, area, and yield of the main governorates in Egypt (1990-2012).*

Year	Wheat Production (Thousand Ton)	Wheat Area (Thousand Hectare)	Wheat Yield (Ton/Hectare)
1990	327.34	58.49	5.60
1991	333.90	63.45	5.26
1992	338.86	58.96	5.75
1993	356.67	58.83	6.06
1994	328.05	57.70	5.69
1995	400.22	67.42	5.94
1996	416.37	66.25	6.28
1997	419.33	70.04	5.99
1998	434.30	67.38	6.45
1999	454.32	67.45	6.74
2000	486.66	73.19	6.65
2001	457.63	68.57	6.67
2002	468.13	71.18	6.58
2003	506.70	74.04	6.84
2004	522.99	76.15	6.87
2005	586.88	86.68	6.77
2006	574.69	89.79	6.40
2007	531.09	79.21	6.71
2008	577.09	89.51	6.45
2009	628.52	94.84	6.63
2010	525.03	89.08	5.89
2011	606.68	90.83	6.68
2012	631.10	93.52	6.75
Rate[a]	(3.03)	(2.16)	(0.85)

Source: MALR in Egypt and own elaboration.
([a]) Annual average percentage growth rate (1990-2012).

Table 2 - *Main governorates of wheat production in Egypt (1990-2012).*

Governorate	Number on Figure 1	Wheat Production (Thousand Ton) 1990	Wheat Production (Thousand Ton) 2012	Wheat Area (Thousand Hectare) 1990	Wheat Area (Thousand Hectare) 2012	Wheat Yield (Ton/Hectare) 1990	Wheat Yield (Ton/Hectare) 2012
Sharkia	23	487.31	1144.62 (3.96)	90.97	178.52 (3.11)	5.36	6.41 (0.82)
Dakahlia	7	519.00	879.14 (2.42)	87.74	127.38 (1.71)	5.92	6.90 (0.70)
Behairah	4	385.80	930.94 (4.09)	75.60	135.04 (2.67)	5.10	6.89 (1.38)
Menia	15	328.70	618.68 (2.92)	56.49	91.84 (2.23)	5.82	6.74 (0.67)
Fayoum	9	228.70	491.25 (3.54)	41.33	73.43 (2.65)	5.53	6.69 (0.87)
Assuit	3	291.80	537.84 (2.82)	51.07	80.18 (2.07)	5.71	6.71 (0.73)
Suhag	24	294.70	496.56 (2.40)	59.81	73.52 (0.94)	4.93	6.75 (1.44)
Gharbia	10	266.30	436.94 (2.28)	45.74	63.43 (1.50)	5.82	6.89 (0.77)
Beni Suef	5	220.00	360.26 (2.27)	36.20	52.97 (1.75)	6.08	6.80 (0.51)
Menoufia	16	211.40	406.06 (3.01)	35.41	53.17 (1.87)	5.97	7.64 (1.13)
Kafr Elshikh	13	367.00	639.85 (2.56)	63.00	99.24 (2.09)	5.83	6.45 (0.46)
Total		3600.71	6942.14 (3.03)	643.36	1028.71 (2.16)	62.06	74.87 (0.86)

Sources: MALR in Egypt and own elaboration
Note: Figures in parentheses are annual average percentage growth rates (1990-2012).

Table 3 - *Summary statistics for variables in the stochastic frontier production function.*

Variables	Units	Maximum	Minimum	Mean	Std. Dev.
Output (y_{it})	Tons (thousands)	1144.62	195.00	474.46	192.47
Land (x_{1it})	Hectares (thousands)	178.52	20.92	74.46	29.22
Labor (x_{2it})	Hours (thousands)	110466.20	13191.72	46973.43	18421.22
Machinery (x_{3it})	Hours (thousands)	12321.23	1045.38	4325.39	1799.44

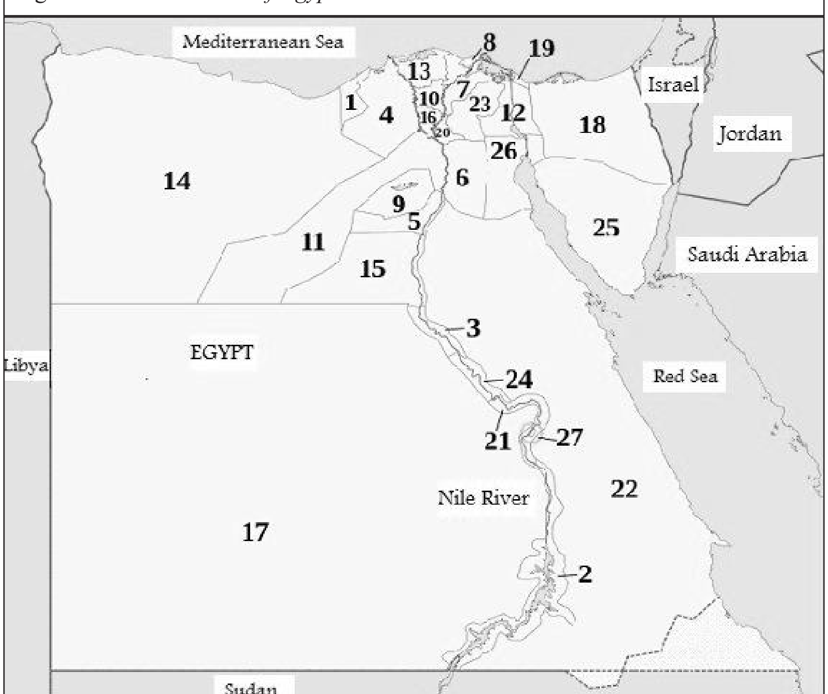
Source: Own elaboration from the data (Ministry of Agriculture and Land Reclamation, Egypt).

(4.09%), Sharkia governorate had the highest annual average percentage growth rate of wheat area (3.11%), and Suhag governorate had the highest annual average percentage growth rate of wheat yield (1.44%).

Egypt is divided for administrative purposes into 27 governorates. Figure 1 shows the main governorates of wheat production in Egypt.

The data employed for the stochastic frontier analysis are taken from the Ministry of Agriculture and Land Reclamation (MALR), Egypt; and Central Agency for Public Mobilization and Statistics (CAPMAS), Egypt. The panel data composed of 253 observations for eleven governorates represents the main governorates of wheat production in Egypt during the time period 1990-2012. The summary statistics for the variables used in the analysis are presented in Table 3. The production inputs comprise three input variables (land, labor and machinery) while there is only one output (wheat production). Wheat production is expressed in thousand tons and land in thousand hectares. Labor and machinery have been estimated in thousand hours.

Figure 1 - *Governorates of Egypt.*



Sources: MAPS.com, Wikipedia, and own elaboration.
Note: The main governorates of wheat production in Egypt during the time period 1990-2012 shown at table 2.

6. Results

The Maximum Likelihood estimates of Battese and Coelli (1992) and (1995) specifications for the main governorates of wheat production in Egypt are presented in Table 4. The coefficients of the Cobb-Douglas production function can be directly illustrated as production elasticities of inputs in the production process. Both estimates are preferred to the OLS model, since the likelihood ratio tests ($\gamma=\mu=\eta=0$ and $\gamma=\delta_0=\delta_1=\delta_2=\delta_3=\delta_4=0$, Table 4) reject the null in favor of the stochastic frontier models, which indicates the relevance of technical inefficiency in explaining output variability among the main governorates of wheat production.

The Maximum Likelihood estimates of Battese and Coelli (1992) specification for the main governorates of wheat production in Egypt shows that the coefficient of land is positive and significant according to the prior expectations. The coefficient of labor is positive and significant. The coefficient of machinery is negative and insignificant. This may be due to that the average farm size in Egypt is about 0.6 hectare (FAO, 2006). In the small farm size, machinery cannot work efficiently and this requires the implementation of land consolidation system (Hõna, 2005) to increase the efficiency of machinery and reduce costs. The technical change coefficient is positive and insignificant.

The Maximum Likelihood estimates of Battese and Coelli (1995) specification for the main governorates of wheat production in Egypt shows that the coefficients of land is significant and hence, playing a major role in the wheat production. The coefficient of land is positive and highly significant according to the prior expectations. The coefficient of labor is positive and insignificant. This may be due to the lack of training for labors. The coefficient of machinery is negative and insignificant. The technical change coefficient is positive and significant. This result indicates a small technical progress over time. The evidence in other empirical works is not conclusive, for example Coelli and Battese (1996), in their study of three semi-arid villages in India, report the three possible cases, that is, technical progress, technical regress and no technical change.

Taking into account the logarithmic value of the likelihood function of the two specifications, the higher logarithmic value of the likelihood function of Battese and Coelli (1995) specification indicates a better specification of this model.

Table 4 - *Maximum Likelihood estimates of the Cobb-Douglas stochastic frontier production function.*

	Battese and Coelli (1992) specification		Battese and Coelli (1995) specification	
Variables	**Coefficients**	**Standard error**	**Coefficients**	**Standard error**
Frontier Production Function				
Constant	0.5802	(0.9777)	0.8612	(0.9799)
Land (x_{1it})	0.5798	(0.2838)*	0.7362	(0.1561)***
Labor (x_{2it})	0.3379	(0.1540)**	0.2143	(0.1547)
Machinery (x_{3it})	-0.0611	(0.1297)	-0.0185	(0.0402)
time *(t)*	0.0071	(0.0128)	0.0032	(0.0014)**
Inefficiency Effects				
Constant			-0.0796	(0.5779)
Dummy variable (Z_{1it})			0.0089	(0.5777)
Dummy variable (Z_{2it})			-0.0885	(0.5775)
time variable (Z_{3it})			-0.0195	(0.0041)***
Dummy variable (Z_{4it})			0.0534	(0.0372)
Sigma-squared (σ^2)	0.0068	(0.0087)	0.0080	(0.0010)***
Gamma (γ)	0.0940	(0.7604)	0.2707	(0.1332)*
Mu (μ)	0.0064	(0.6163)		
Eta (η)	0.0737	(0.2720)		
Log likelihood function	264.3412		268.5402	
LR test	19.8840***($\gamma=\mu=\eta=0$)		28.2820***($\gamma=\delta_0=\delta_1=\delta_2=\delta_3=\delta_4=0$)	
LR test			11.6984**($\delta_1=\delta_2=\delta_3=\delta_4=0$)	
Total number of observations	253		253	

***, ** and * indicates significance at 1, 5 and 10% level, respectively.
All the variables are in log form except dummies and time.

The gamma coefficient for the latter (0.2707) points out that both statistical noise and inefficiency are important. The proportion of total variance that is due to inefficiency is estimated to be $\sigma_u^2/(\sigma_u^2+\sigma_u^2)$=11.88%.

In order to investigate the determinants of technical inefficiency we estimated the technical inefficiency model defined by equation 3, where technical inefficiency is assumed to be dependent variable. The dummy variables coefficients (Z_1 and Z_2) are insignificant, this indicates that the location of the governorates does not have any impact on the wheat production. The negative and statistically significant coefficient of the time variable (Z_3) indicates that the technical inefficiency of wheat production in Egypt tended to decrease through the period of study. Therefore wheat production in Egypt become more efficient over time. The dummy variable coefficient of gender (Z_4) is insignificant, which indicates that there is no impact from the gender on the wheat production in Egypt. But the joint effects of these four explanatory variables on the inefficiencies of production is significant at 5% level (LR test ($\delta_1=\delta_2=\delta_3=\delta_4=0$), Table 4) although the individual effects of the variables Z are not always significant.

Table 5 shows the annual levels of technical efficiency of the total sample. The annual levels of technical efficiency are quite similar. The mean of technical efficiency for the time period 1990-2012, vary from a minimum level of 0.9444 (Battese and Coelli (1992) to a maximum level of 0.9630 (Battese and Coelli (1995), and the mean of the two specifications is 0.9537. The two specifications make clear improving in the levels of technical efficiency during the time period 1990-2012. The annual average percentage growth rates vary from 0.4150% (Battese and Coelli (1992) to 0.5583% (Battese and Coelli (1995), and the mean of the annual average percentage growth rate of the two specifications is 0.4867%.

Table 6 presents the mean of technical efficiency for the different governorates during the time period 1990-2012. Fayoum governorate has the minimum mean level of technical efficiency (0.9161) of the specifications of Battese and Coelli (1992) and (1995), while Dakahlia governorate has the maximum mean level of technical efficiency (0.9869) of the two specifications.

7. Conclusions

This paper aims to examine the input-output relationship of wheat production and estimate the technical efficiency of the main governorates of wheat production in Egypt during the time period 1990-2012. The data used in this study is a panel data at the governorates level, it represents the time period 1990-2012 and taken from the Ministry of Agriculture and Land Reclamation, Egypt; and the Central Agency for Public Mobilization and Statistics, Egypt. We apply the stochastic frontier approach for efficiency measurement and the Cobb-Douglas production function is used. The specifications of Battese and Coelli (1992) and (1995) are employed. The coefficient of land is positive and significant at Battese and Coelli (1992) and (1995) specifications, implying that increasing the wheat area could significantly enhance the production of wheat. The coefficient of labor is positive and significant at Battese and Coelli (1992) specification, while it is positive and insignificant at Battese and Coelli (1995) specification. The coefficient of machinery is negative and insignificant at the specifications of Battese and Coelli (1992) and (1995). The technical change coefficient is positive and insignificant at Battese and Coelli (1992) specification, while it is positive and significant at Battese and Coelli (1995) specification.

The variables of the inefficiency effect model indicate that there is no impact from the location of the different governorates on wheat production in Egypt, the technical inefficiency of wheat production tended to decrease through the period of study, and there is no impact from the gender on wheat production in Egypt. The levels of technical efficiency vary among the different governorates for the specifications of Battese and Coelli (1992) and (1995); the minimum mean level of technical efficiency is 91.61% at

Table 5 - *Technical efficiency by year.*

Year	Technical efficiency Battese and Coelli (1992) specification	Technical efficiency Battese and Coelli (1995) specification	Minimum	Maximum	Mean
1990	0.8922	0.8786	0.8786	0.8922	0.8854
1991	0.8993	0.8763	0.8763	0.8993	0.8878
1992	0.9059	0.9050	0.9050	0.9059	0.9055
1993	0.9122	0.9255	0.9122	0.9255	0.9189
1994	0.9181	0.9224	0.9181	0.9224	0.9203
1995	0.9236	0.9405	0.9236	0.9405	0.9321
1996	0.9287	0.9543	0.9287	0.9543	0.9415
1997	0.9335	0.9596	0.9335	0.9596	0.9466
1998	0.9381	0.9698	0.9381	0.9698	0.9540
1999	0.9421	0.9768	0.9421	0.9768	0.9595
2000	0.9462	0.9789	0.9462	0.9789	0.9626
2001	0.9499	0.9822	0.9499	0.9822	0.9661
2002	0.9533	0.9810	0.9533	0.9810	0.9672
2003	0.9566	0.9866	0.9566	0.9866	0.9716
2004	0.9596	0.9879	0.9596	0.9879	0.9738
2005	0.9624	0.9885	0.9624	0.9885	0.9755
2006	0.9650	0.9884	0.9650	0.9884	0.9767
2007	0.9674	0.9900	0.9674	0.9900	0.9787
2008	0.9697	0.9899	0.9697	0.9899	0.9798
2009	0.9718	0.9916	0.9718	0.9916	0.9817
2010	0.9737	0.9903	0.9737	0.9903	0.9820
2011	0.9756	0.9927	0.9756	0.9927	0.9842
2012	0.9773	0.9931	0.9773	0.9931	0.9852
Mean (1990-2012)	0.9444	0.9630	0.9428	0.9647	0.9537
Rate[a]	0.4150	0.5583	0.4851	0.4882	0.4867

Source: Own elaboration.
([a]) Annual average percentage growth rate (1990-2012).

Fayoum governorate, while the maximum mean level of technical efficiency is 98.69% at Dakahlia governorate. The technical efficiency takes an average value of 95.37%, this implying that little potential exists to improve resource use efficiency in wheat production. From this work we suggest the following recommendations, increase the area of wheat production through the reclaimed agricultural areas; implement the land consolidation system to increase the efficiency and reduce the costs; improve and increase the training of labor, especially the skills of cultivation and harvesting of wheat; improve the technology of wheat production; and increase the research with the purpose of taking advantage of genetic improvements, which should enable the introduction of new wheat varieties with higher productivity. Future works need to obtain extensive data on the variables of production frontier and the model of inefficiency effect, through the surveys. With the use of surveys it is possible to investigate the socio-economic factors (age, education, composition of labor, size of farm, quality of land, property of land, etc) that could affect the technical efficiency in different farms and governorates.

Table 6 - Technical efficiency by governorate[a].

Governorate	Technical efficiency Battese and Coelli (1992) specification	Technical efficiency Battese and Coelli (1995) specification	Minimum	Maximum	Mean
Sharkia	0.9705	0.9711	0.9705	0.9711	0.9708
Dakahlia	0.9908	0.9829	0.9829	0.9908	0.9869
Behairah	0.9725	0.9720	0.9720	0.9725	0.9722
Menia	0.9804	0.9528	0.9528	0.9802	0.9666
Fayoum	0.8924	0.9398	0.8924	0.9398	0.9161
Assuit	0.9296	0.9457	0.9296	0.9457	0.9377
Suhag	0.9089	0.9413	0.9088	0.9413	0.9251
Gharbia	0.9243	0.9801	0.9243	0.9801	0.9522
Beni Suef	0.9328	0.9621	0.9328	0.9621	0.9475
Menoufia	0.9199	0.9713	0.9199	0.9713	0.9456
Kafr Elshikh	0.9668	0.9744	0.9668	0.9744	0.9706

Source: Own elaboration.
([a]) Mean of the time period (1990-2012).

References

Aigner D.J., Lovell C.A.K. and Schmidt P.J., 1977. Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics* 6 (1): 21-37.

Battese G.E. and Coelli T.J., 1992. Frontier production functions, technical efficiency and panel data: With application to paddy farmers in India. *Journal of Productivity Analysis* 3: 153-169.

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.

Bravo-Ureta B.E. and Pinheiro A.E., 1993. Efficiency analysis of developing country agriculture: A review of the frontier function literature. *Agricultural and Research Economic Review* 22 (1): 88-101.

CAPMAS, 1990-2012. *Statistical Yearbook.* Central Agency for Public Mobilization and Statistics, Egypt.

Coelli T.J., 1996. *A guide to Frontier Version 4.1: A computer program for stochastic frontier production and cost function estimation*. Centre for Efficiency and Productivity Analysis, University of New England, Armidale, Australia. CEPA working paper, 7/96.

Coelli T.J. and Battese G.E., 1996. Identification of factors which influence the technical inefficiency of Indian farmers. *Australian Journal of Agricultural Economics* 40 (2): 103-128.

Coelli T.J. and Perelman S., 2000. Technical efficiency of European railways: A distance function approach. *Applied Economics* 32: 1967–1976.

Coelli T.J., Prasada Rao D.S., O'Donnell C.J. and Battese G.E., 2005. *An in-*

troduction to efficiency and productivity analysis. 2nd ed. Springer.

Covaci S. and Sojková Z., 2006. Investigation of wheat efficiency and productivity development in Slovakia. *Agricultural Economics.-Czech* 52 (8): 368-378.

Croppenstedt A., Saade M. and Siam G.M., 2006. *Food security and wheat policy in Egypt. Roles of Agriculture Project Policy Brief*. Rome: FAO.

FAO, 2006. *Fertilizer Use by Crop*. Rome: FAO. Fertilizer and Plant Nutrition Bulletin, 17.

FAO, 2011. *Egypt production potential. Egypt - FAO Wheat Database*. Rome: FAO.

Fried H., Lovell C.A.K., and Schimdt S. (eds.), 2008. *The measurement of productive efficiency and productivity growth*. New York: Oxford University Press.

Ghaderzadeh H. and Rahimi M.H., 2008. Estimation of technical efficiency of wheat farms: A case study in Kurdistan province, Iran. *American-Eurasian Journal of Agriculture & Environmental Sciences* 4 (1): 104-109.

Gowayed S., 2009. *Egyptian wheat*. University of Kassel, Germany. Department of Agrobiodiversity, Institute of Crop Sciences, Doctoral Dissertation.

Goyal S.K. and Suhag K.S., 2003. Estimation of technical efficiency on wheat farms in Northern India - A panel data analysis. In: *14th International Farm Management Congress, Western Australia, Burswood Convention Centre, Perth, August 10th to 15th*.

Hassan S. and Ahmad B., 2005. Technical efficiency of wheat farmers in mixed farming system of the Punjab, Pakistan. *International Journal of Agriculture & Biology* 7 (3): 431-435.

Headey D., Alauddin M. and Rao D.S.P., 2010. Explaining agricultural productivity growth: An international perspective. *Agricultural Economics* 41: 1-14.

Hõna E., 2005. The role of spatial plans in the preparation of land consolidation in Hungary. In: *From pharaohs to geoinformatics. FIG Working Week and GSDI-8, Cairo, Egypt, April 16-21.*

Hossain M.K., Kamil A.A., Baten M.A. and Mustafa A., 2012. Stochastic frontier approach and data envelopment analysis to total factor productivity and efficiency measurement of Bangladeshi rice. *PLOS ONE* 7 (10), e46081.

Kachrooa J., Sharmaa A. and Kachroo D., 2010. Technical efficiency of dryland and irrigated wheat based on stochastic model. *Agricultural Economics Research Review* 23: 383-390.

Kaur M., Mahal A.K., Sekhon M.K. and Kingra H.S., 2010. Technical efficiency of wheat production in Punjab: A regional analysis. *Agricultural Economics Research Review* 23: 173-179.

Kherallah M., Löfgren H., Gruhn P. and Reeder M.M., 2000. *Wheat policy reform in Egypt. Adjustment of local markets and options for future reforms*. Washington, D.C.: IFPRI. Research Report, 115.

Koopmans T.C., 1951. *Analysis of production as an efficient combination of activities. In:* Koopmans T.C. (ed.). *Activity analysis of production and allocation*. New York: Wiley, pp. 33-97.

MALR, 1990-2012. *Agricultural statistics*. Economic Affairs Sector, Ministry of Agriculture and Land Reclamation, Egypt.

Meeusen W. and van den Broeck J., 1977. Efficiency estimation from Cobb-Douglas production functions with composed error. *International Economic Review* 18 (2): 435-444.

O'Donnell C.J. and Coelli T.J., 2005. A Bayesian approach to imposing curvature on distance functions. *Journal of Econometrics* 126 (2): 493-523.

Reddy A.A., 2012. Sources of agricultural productivity growth in Orissa: A district level analysis. *The Journal of Income and Wealth* 34 (2): 89-105.

Silva E., Arzubi A. and Berbel J., 2014. An application of Data Envelopment Analysis in Azores Dairy Farms. *New Medit*, 13(3): 30-43.

Sotnikov S., 1998. Evaluating the effect of price and trade liberalization on the technical efficiency of agricultural production in a transition Economy: The case of Russia. *European Review of Agricultural Economics,* 25 (3): 412-431.

Tyner W., Morse B.A., El Amir M.R., Mostafa A. and Sherif S., 1999. *Wheat subsector baseline study.*, Abt Associates. Report, 6.

USDA, 1997. *Grains: world markets and Trade, Part one*. Grain and feed division, commodity and marketing programs, Foreign Agricultural Service, United States Department of Agriculture, Washington DC.