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REVIEW ARTICLE

Economic efficiency of wheat production in Gezira scheme, Sudan ☆

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KEYWORDS

Stochastic analysis;
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Conventional random variability

Abstract This study was carried out in Gezira scheme (season 2007/08) to measure the farmer's technical efficiency of producing wheat and to determine the main socio-economic factors affecting farmer's technical efficiency of wheat production. The stochastic production frontier model was employed to achieve the study objectives. Primary data was collected from a random sample of 60 farmers in the Gezira scheme by mean of a structured questionnaire. The primary data was supplemented by secondary data collected from different relevant sources. The study results showed that the mean technical efficiency of wheat production is 63% which means that wheat production could have been increased by 37% at the same level of inputs, had resources efficiently utilized. The main socio-economic factors determining the farmer's technical efficiency appeared to be: the timing of the different agricultural operations, irrigation and land ownership.

To improve wheat production technical efficiency, the study recommended usage of wheat improved varieties and application of the different agricultural operations, particularly land preparation and irrigation, at the optimum timing.

☆ Extracted from the the M.Sc. thesis of the second author.

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Contents

1. Introduction

The agricultural sector is the mainstay of the Sudanese economy. It contributes about 41% of the GDP, 80% of exports (excluding oil). Agriculture employs 65% the labor force and provides 50% of the raw material for the industrial sector. Although these contributions seem substantial, but they are considered humble, compared to the natural resources and potentialities of the sector. This modest performance is due to inadequate investments in agriculture which is manifested in poor infrastructure, low technical capacities of labor force, poor support services including research and extension and shortages of the necessary inputs such as improved seed, and fertilizers.

The Gezira scheme has always been encumbered by a unique institutional setup which reduced the managerial and economic efficiency of the scheme. The current production relations, including centralized decision-making on production and marketing of major crops and centralized management of irrigation water limit the options of farmers for an efficient allocation of resources and affect their benefits substantially. Pan-territorial charges and payments provide fewer incentives for farmers. The performance is further aggravated by the deterioration of the infrastructure and absence of technical progress.

As a result, inefficient and wasteful water distribution became the rule and expansion in acreage and productivity of crops was limited. A typical farm has become unable to provide an income above the poverty line for an average family in Gezira scheme. Educated farmers have found alternative income sources and do not rely fully on agriculture for their livelihood (Rahman, 2002). In line with this, some other studies found that the major factors contributing to efficiency of production were age of farmers, level of education and family size.

Wheat cultivation has been known in northern Sudan but the area cultivated has never exceeded 1500 ha up to the end of the fifties. The output was enough to cover the consumption needs in northern Sudan and the main towns. The rest of the population depends on sorghum in central and eastern Sudan, dukhn in the west and cassava in the south. All these crops, with the exception of wheat are produced under rains (Ministry of Agriculture and Forestry, 2007). Wheat consumption in Sudan has been sharply increasing from about 220,000 ton in 1970/71 to about 2,000,000 ton in 2007, due to the population growth and the rising per capita consumption. However, in the following years of policy liberalization and issuing inflation, the cost of production became prohibitive and wheat production was sharply reduced prompting the country to import most of its wheat requirements. At present, the Gezira scheme produces more than 50% of the country's wheat production; the rest is produced in the Northern and Nile states in addition to little areas in Rahad and New Halfa schemes (Ministry of Agriculture and Forestry, 2007).

The Sudan wheat situation is characterized by rapid consumption growth, continuous and variable deficit between domestic needs and local production and uncertain estimates of actual wheat demand due to quota and price control. Current average wheat yields are quite variable and substantially lower than the potential. Space variability, induced by confounded effects of location, management and tenant preferences, call for some level of specialization and vertical increase in production in contrast to the current area expansion strategies (Faki, 1996).

1.1. Definitions of terms

This part defines some terms that are commonly used in efficiency analysis.

The efficiency analysis, in general, focuses on the possibility if producing a certain level of output at the lowest cost or producing an optimal level of output from a given resources (Russell and Young, 1983).

Economic efficiency (EE) is the degree or ability of a farmer to produce a given level of output at the least cost. EE could be divided into allocative efficiency (AE) and technical efficiency (TE) (Farrell, 1957). AE refers to the appropriate choice of input combination. A farm is allocatively efficient if production inputs are allocated according to their relative prices. TE refers to the proper choice of production function among all those actively in use by farmers. A farm is technically efficient if it produces the maximum obtainable output level from a certain amount of inputs, given its technology.

The stochastic production frontier is an econometric technique that allows the measurement of efficiency as defined by the ratio of observed output to the estimated (maximum) output, defined by the frontier production function, given inputs and stochastic nature of production.

2. Objectives

The main objective of this study was to measure the economic efficiency of wheat production in Gezira scheme and to explain the possibilities of increasing productivity and profitability of wheat by increasing the farmer's efficiency in production. Specifically, the study tried to measure wheat production technical efficiency and identifies its determinants and the main factors affecting it. In addition, the study tried to come out with policy recommendation to help decision-makers increase what productivity in Gezira a scheme.

3. Methodology

The stochastic production frontier (SPF) functions have been the subject of considerable econometric research during the past two decades (Farrell, 1957). The econometric technique developed by Coelli et al. (1998) allows for the measure of technical efficiency as defined by the ratio of observed output to the maximum output defined by the SPF function, given inputs and stochastic variation. However deviations from the production frontier may not be entirely under control of the production unit under study (Battesee and Corra, 1977; Meeusen and Broeck, 1977). Ahmed (2007) cited that the measure of firm efficiency consists of two components: technical efficiency (TE) which reflects the ability of a firm to obtain the maximum output from a given set of inputs and allocative efficiency (AE) which reflects the ability of the firm to use the inputs in optimal proportions, given their respective prices. These two measures combine to provide a measure of the economic efficiency. The function can be estimated from a sample data using a non-parametric piece wise-linear technique or a parametric function such as the Cobb–Douglas production function. The model is defined by:

$$\ln(Y_i) = X_i\beta - U_i, \quad i = 1, 2, \ldots, N \tag{1}$$

where In Y_i is the natural logarithm of the (scalar) output of the i-th firm. X_i is a $(K+1)$-row vector whose first element is "1" and the remaining elements are the natural logarithm the K-input quantifies used by the i-th firm. $\beta = (\beta_0, \beta_1, \ldots, \beta_k)$ is a $(K+1)$-column vector of unknown parameters to be estimated and U_i is a non-negative random variable associated with the technical inefficiency in production of firms is the industry involved.

The ratio of observed output for the i-th firm, relative to the potential output defined by the SPF function, given the input vector X_i, is used to define the technical efficiency (TE) of the i-th firm:

$$TE_i = \frac{Y_i}{\exp(X_i\beta)} = \frac{\exp(X_i\beta - U_i)}{\exp(X_i\beta)} = \exp(-U_i) \tag{2}$$

Aigner et al. (1977) model proposed a SPF function in which an additional random error (V_i) is added to the non-negative random variable U_i, in Eq (1) to provide:

$$\ln(Y_i) = X_i\beta + V_i - U_i, \quad i = 1, 2, \ldots, N \tag{3}$$

They also expressed the likelihood function in terms of two variance parameters, $\delta_s^2 = \delta_v^2 + \delta^2$. Battesee and Corra (1977) suggested the parameter $\gamma = \delta^2/\delta_s^2$ be used because it has a value between zero and one and could be of any non-negative valve. A γ value of zero means that the deviations from the frontier are entirely due to noise or uncontrollable factors, while a value of one would indicate that all deviations are due to technical inefficiencies.

The study objectives are achieved through the estimation and analysis of the SFP model. The most commonly used package for estimation of SFP is FRONTIER 4.1 (Coelli, 1996).

The efficiency model includes factors influencing tenant technical efficiency for wheat production. The model is specified as follows:

$$\text{In}\, Y_i = \beta_0 + \beta_{1D1}X_{il} + \sum \infty_j = 2\beta_j \text{In} X_{ij} + V_i - U_i$$

where ln is the natural logarithm, Y_i is the yield wheat in sack/feddan, X_i is the wheat area (feddans), D_1X_{i2} is the dummy variable for ownership which has value of one if land is owned and zero if land is hired, D_2X_3 is the dummy variable for varieties which has value of one for indigenous (imam and sasrable) varieties is owned and zero improved varieties. D_3X_{i4} is the land preparation dummy variable with a value of one if land is prepared at the optimum time and zero if land preparation is late. D_4X_5 is the extension services dummy variable with value of one if available and zero if not available. β_1 and β_j are unknown parameters to be estimated for the dummy and the continuous variables, respectively. V_i is the statistical error representing factors beyond tenant control such as weather and other factors not included in the model. V_i could be positive, negative or zero. U_i is a non-negative random variable associated with tenant technical inefficiency in production and is assumed to be independently distributed.

The technical inefficiency effect for the i-th tenant, U_i, is obtained by the truncating (at zero) of the normal distribution with mean μ_i and variance δ^2 such that:

$$\mu_i = \delta_0 + \sum \delta_s Z_s$$

where Z_{1i} is the gender dummy variable: with value of one if tenant variable is male or two if tenant is female, Z_{2i} is the age of tenant, Z_{3i} is the family size, Z_{4i} is the education dummy variable with value of one if tenant is illiterate, two if has Khalwa education, three if has primary education, four if has secondary education and five if has university or post-graduate education, Z_{5i} is the farm location dummy variable, Z_{6i} is the number of delayed irrigations, Z_{7i} is the number of insufficient irrigations, Z_{8i} is the marital stare dummy variable with value of one if tenant is single and two if tenant is married, δ_0 and δ_s^2 are unknown parameters to be estimated.

To allow the estimation of these models, primary data were collected from a random sample of 60 farmers in Gezria scheme using a structured questionnaire.

The collected primary data were supplemented with secondary data collected from different relevant sources.

4. Results and discussion

Table 1 presents the Z-values for the tests of the stochastic frontier production function hypotheses.

As Table 1 shows, both null hypotheses are rejected which means that, the deviations from normal are not entity due to noise (first assumption), and some technical inefficiencies are present in the model (second assumption). These inefficiencies are assumed due to both controllable as well as uncontrollable (random) factors.

Table 2 presents the parameter estimates of the stochastic production frontier function.

The variance ratio parameter (γ) has a value of 0.96 which means that 96% of wheat output derivations are caused by differences in farmers' levels of technical efficiencies as opposite to the conventional random variability. The significant estimates of γ and δ^2 imply that the assumed distributions of U_i and V_i are acceptable. The mean technical inefficiency of wheat production is estimated as 0.63 which means that the scheme produces 63% of wheat at best practice, at the current levels of production input and technology. In other words, wheat output could have been increased by 37% at same levels of

Table 1 Tests of the stochastic production frontier hypotheses.

Hypothesis	Z-values	Decision
H_0: $\gamma = \mu = 0$ (deviation entirely due to noise)	28.8***	H_0: rejected
LR H_0: no technical inefficiency	51.5***	H_0: rejected

Source: Estimated by model, 2010.
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.

Table 2 Parameters estimates of the stochastic production frontier function.

Variables	Parameters	Estimates
Constant	β_0	0.23 (0.50)
Area (X_1)	β_1	0.84*** (0.10)
Ownership (X_2)	β_2	0.23* (0.13)
Variety (X_3)	β_3	−0.49** (0.21)
Land preparation (X_4)	β_4	−0.69*** (0.12)
Extension services (X_5)	β_5	−0.69*** (0.15)
$\delta_s^2 = \delta_v^2 + \delta^2$	$\delta_s^2 = \delta_v^2 + \delta^2$	0.22** (0.11)
$\delta = \delta^2/\delta_s^2$	$\delta = \delta^2/\delta_s^2$	0.96*** (0.33)
Mean efficiency		0.63
Log likelihood function		0.52

Source: Estimated by model, 2010.
Note: Values between brackets are the standard errors of the parameters.
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.

Table 3 Wheat production inefficiency model parameters.

Variables	Parameters	Estimates
Constant (Z_0)	δ_0	−0.42* (0.24)
Gender (Z_1)	δ_1	−0.35* (0.21)
Age (Z_2)	δ_2	−0.39* (0.24)
Family size (Z_3)	δ_3	0.69*** (0.12)
Educational level (Z_4)	δ_4	0.98 (0.71)
Farm location (Z_5)	δ_5	0.33 (0.42)
# of delayed irrigations (Z_6)	δ_6	−0.76** (0.37)
# of insufficient irrigations (Z_7)	δ_7	−0.64** (0.30)
Marital starts (Z_8)	δ_8	0.34 (0.33)
Mean efficiency		0.63
Likelihood function		0.52

Source: Estimated by model, 2010.
Note: Values between brackets are the standard errors of the parameters.
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.

inputs had farmers been technically efficient. It is worth mentioning that Moez (2008) estimated technical efficiency for Managel extension farmers as 73% which means that they are technically more efficient than Gezira scheme farmers.

Almost, all estimated β coefficients have the expected signs. As the positive β_1 reads, area is positively related to wheat yield which means that farmers who cultivate additional lands have the ability to maintain reasonable levels of the necessary inputs, otherwise, additional area need not increase wheat yield if the levels of inputs are not maintained. Al-Feel (1993) and Moez (2008) have similar results.

The positive coefficient of land ownership variable indicates that land owners achieve more output as compared to land renters. There is a lot of discussion in the literate about this issue. The assumption is that land owners always exert more efforts in agricultural production compared to land renters because of the incentives they have. This result indicates that land owners are more efficient in wheat production relative to land renters. The varieties' coefficient have a negative sign indicating that indigenes varieties (imam or sasrable) are of low yield compared to improved varieties which means that farmers using improved varieties are more efficient. This result calls for usage of wheat improved verities. The coefficient of land preparation variable has a negative sign which means that land preparation is done later than required and this inefficiency results in decreased output (yield). Late land preparation is a common practice in Gezira scheme, in particular, and in irrigated schemes, in general. The reason is the late arrival of machinery, spare parts and fuel. Late land preparations results in delays of all other agricultural operations as sowing, irrigation and weeding. The results are low yields and less output indicating a significant inefficiency. Ahmed (2007) and Moez (2008) have similar results. The coefficient of extension services variable has a negative sign which means that the available extension services operate on a function lower than that of the optimum (required) extension services. The ratio of needed extension officers to farmers is 1:7000 (World Bank, 2000). This lower function says that the effects all other inputs on the dependent variable is affected by this inefficient extension services.

Table 3 presents the parameters of the wheat inefficiency model. In the model specification, it is well understood that a negative sign means that the specified variable is operating on function lower than the original function. The means that technical inefficiency decreases and accordingly the effects of all other variables on the dependent variables are affected by this lower position of the estimated function. The end result is that the technical inefficiency is less on this lower function.

As the figures of Table 3 read, the gender, the age, the number of insufficient irrigations and the number of delayed irrigations coefficients, all have negative signs which means that the inefficiency decreases when the farm owner is male, young and the number of insufficient irrigations and the number of delayed irrigation are less.

Moez (2008) found very similar results. The family size positive coefficient implies that inefficiency decreases with the increase of family size, as the additional family members are reflected as additional labor.

Other variable coefficients are not significantly different from zero at any reasonable level. However, Moez (2008) found a significant relationship between farm location and inefficiency. He found that farmers located at the head of the irrigation canals are more efficient than those located at the tail of the irrigation canals. Of course, this effect is reflected in the number of delayed and number of insufficient irrigations.

5. Conclusions

Agricultural productivity varies according to the differences in production technologies and differences in the efficiency of the production process. The stochastic production frontier function with the specification of the Cobb–Douglas production function effectively modeled the technical efficiency of wheat production in Gezira scheme. The model was used as well to identify the most important socio-economic factors that affect farmers' technical efficiency in wheat production. The results showed that the technical efficiency of wheat production in Gezira scheme is 0.63 which means that the scheme produces 63% of wheat at best practice, at the current levels of production inputs and technologies. In other words, wheat production could have increased by 37% at the same level of inputs had farmers been technically efficient. The results also showed that 96% of wheat output deviation from normal is due to differences in farmers' level of technical efficiencies as opposite to the conventional random variability. Area of wheat, varieties, land ownership, land preparation and extension services, appeared to be the main factor determining wheat yield in Gezira scheme. The farmer gender, the farmer age, the family size, the number of delayed and/or insufficient irrigations appeared to be the most important socio-economic factors determining farmers' efficiencies in wheat production in Gezira scheme.

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