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Technical Efficiency of Wheat Production in the Gezira Scheme

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Abstract: This study was carried out to measure the technical efficiency of wheat production in the Gezira scheme and to determine the most important socio-economic factors affecting this efficiency, using the stochastic production frontier model. Primary and secondary data were used. The former were collected from a random sample of 100 farmers from Waddel Mansi sector of the Gezira scheme, while the latter were collected from relevant sources. The results showed that the mean technical efficiency was 0.73, which means that the scheme produced 73% of the possible wheat production at the current levels of production inputs and technology. In other words, wheat production could have been increased by 27%, at the same levels of inputs had farmers been technically efficient. The results also showed that 97% of wheat output deviations from normal were caused by differences in farmers' levels of technical efficiencies and were not due to the out of control random nature of the agricultural production. Wheat area, sowing date, degree of infection with pests and diseases, number of insufficient irrigations and farmers' experience appeared to be the most important factors determining wheat output in the Gezira scheme. The off-farm income appeared to have negative effects on wheat production, because of its timing contradictions with some important agricultural operations. The farmers' gender, land tenure, land preparation, marital status and farm location with respect to the irrigation canal, represented the most important socio-economic factors determining farmers' efficiencies of wheat production in the Gezira scheme.

Key words: Stochastic; frontier; technical; efficiency; allocative; conventional; random

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INTRODUCTION

Agriculture is the main occupation of the majority of the people of Sudan, and agricultural production is the corner stone of the Sudanese economy. In 2006, the contribution of agriculture to the GDP accounted to 39.2% (Bank of Sudan 2006). In 1998 (EIU 1998), the sector provides about 80% of the country's exports (excluding oil) and contributes to the livelihood of 80% of its population. The agricultural sector is the source of raw material for processing factories in the country including textiles, sugar, vegetable oil, soap, grain mills, dairies, tanneries and saw mills. These contribute about 17% of the GDP and 20% of foreign exchange earnings (Sudagric 2002).

Wheat cultivation has been known in northern Sudan for a long time, but the area cultivated has never exceeded 1500 ha up to the end of the 1950's. The output was enough to cover the consumption needs in northern Sudan and the main towns. The rest of the population depended on sorghum in central and eastern Sudan, pearl millet in the west and cassava in the south. All these crops, with the exception of wheat are produced under rain (MOAF 2007). Wheat consumption in Sudan has been increasing sharply from about 220 000 tons in 1970/71 to about 2 000 000 tons in 2007. This was due to population growth and rising per capita consumption. However, in the following years of liberalization policy and high inflation, the cost of production became rather prohibitive and wheat production was sharply reduced leading 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 River Nile states in addition to small areas in Rahad and New Halfa schemes (MOAF 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).

The efficiency analysis, in general, focuses on the possibility of producing a certain level of output at the lowest cost or producing an optimal level of output from a given resource (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 and 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.

The objectives of this study were (i) to identity, estimate and evaluate the technical efficiency of wheat production and (ii) to identify the major factors that affect farmers' technical efficiency of wheat production in the Gezira scheme.

METHODOLOGY

The stochastic production frontier (SPF) functions have been the subject of considerable econometric research for a long time (Farrell 1957). The econometric technique developed by Battese and Coelli (1988) 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 (Battese and Corra 1977). Ahmed (2004) indicated that the measure of a firm efficiency consists of two components: technical efficiency (TE) which reflects the ability of a firm to achieve 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

$$\ln Y_i = X_i \beta - U_i, \qquad i = 1, 2,..., N \qquad (1)$$

where

$\ln Y_i$ 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 of the K-input quantifies used by the i-th firm.

$\beta = (\beta o, \beta_1,\ldots, \beta_k)$ is a (K+1) - column vector of unknown parameters to be estimated.

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:

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

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 Ui, in equation (1) to provide:

$$\ln Yi = X_i\beta + V_i - U_i \qquad i=1, 2,..., N \qquad (3)$$

They also expressed the likelihood function in terms of two variance parameters, $\delta^2 s = \delta^2 v + \delta^2$. Battese and Corra (1977) suggested the parameter $\gamma = \delta^2/\delta^2 s$ 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 were 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:

$$\text{In } Y_i = \beta_o + \beta_1 D_1 X_{il} + \Sigma^{\infty}{}_{j=2}\ \beta_j \text{ In } X_{ij} + V_i\text{-}U_i. \qquad (4)$$

where

In = the natural logarithm

Y_i = wheat yield in 90kg sacks/ feddan (one feddan=0.42 ha)

X_i = wheat area in feddans

D_1X_{i2}= dummy variable for sowing date which has value of one if sowing is done at optimum time or zero otherwise

X_3= number of ploughings

D_1X_{i4}= pest and weed control dummy variable with a value of one if tenancy is severely infested or zero otherwise

X_5= number of insufficient irrigations

X_6= agricultural income invested in agriculture during the season

X_7= number of years of tenant's experience

X_8= off-farm income invested in agriculture during the season

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, 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

$$\mu_i = \delta_o + \Sigma\delta_s Z_s \quad (5)$$

where

Z_{1i} = gender dummy variable, with value of one if tenant variable is male and two if tenant is female
Z_{2i}= age of tenant
Z_{3i} = marital status dummy variable with value of one if tenant is single, two if tenant is married and three if divorced
Z_{4i} = education dummy variable with value of one if tenant is illiterate, two if had Khalwa (Qura'an) education, three if had primary education, four if had secondary education and five if had university or post graduate education.
Z_{5i} = family size
Z_{6i} = land tenure dummy variable with value of one if land is owned and two if it is rented
Z_{7i} = harvest date dummy with value of one if harvest is done at the optimum time or zero otherwise
Z_{8i} = land preparation dummy variable with value of two if preparation is done at optimum time or one otherwise
Z_{9i} = farm location dummy variable
δ_0 and δ^2_s are unknown parameters to be estimated

To allow the estimation of these models, primary data were collected from a random sample of 100 farmers in the Gezira scheme by means of a structured questionnaire.
The collected primary data were supplemented with secondly data collected from different relevant sources.

RESULTS AND DISCUSSION

The stochastic frontier version 4.1 program (Coelli 1996) was used to estimate the level of technical efficiency of wheat production in the Gezira scheme. The stochastic production frontier model has two (Z-test) hypotheses. The first assumes that the deviations from normal are entirely due to noise (random variability); while the second assumes that there is no technical inefficiency in the model. The estimated Z-values were 63.3 and 71.3 for the first and the second hypotheses, respectively. Accordingly, both hypotheses were rejected which means that some technical inefficiencies were present in the model, and these inefficiencies were due to both controllable as well as uncontrollable factors.

The mean technical efficiency of wheat production is estimated at 0.73 (Table 1). This average technical efficiency implies that the scheme is working at 73% of its maximum capacity at the current levels of production inputs and technology. This means that wheat output could have been increased by 27% at the current levels of inputs had farmers been technically efficient. The significant estimates of γ and δ^2 imply that the assumed distribution of u_i's and v_i's are acceptable. The 0.97 value of γ expresses that 97% of wheat output deviation were caused by differences in tenants levels of technical efficiencies and were not due the conventional random variability (Table 1). Most of the estimated coefficients have the expected signs, though some of them were not significantly different from zero at any acceptable level. The following discussion includes only the variables which have coefficients that proved significantly different from zero.

The increase of area by 1% increased output by 0.12% which means that increasing area increases efficiency. This may be due to the fact that only rich farmers are able to rent additional lands and are able, at the same time, to apply additional inputs, at the recommended rates and timing.

The coefficient of sowing date has a negative sign indicting that wheat is sown later than the recommended sowing date. This is due to the usual late arrival of inputs which decreases farmers' efficiency (Eisa and Al-Feel 2001). The degree of infection with diseases and infestation with pests decreased efficiency and reduced wheat yield. This is clear from the negative sign of the variable coefficient. The common wheat pests in Gezira include aphids, termites, stem borers and leaf miners (Sharaf Eldin 1993). The coefficient of insufficient irrigation variable indicates that wheat production decreases with increase of insufficient irrigation. Wheat competes with cotton for irrigation water, and the peak demand for water is between October and November. This is the time when insufficient irrigation occurs.

Table 1. Estimates of the parameters of the stochastic production frontier function

Variable	Parameter	Estimate
Constant	β_o	2.81 (0.783)
Area (X_1)	β_1	0.12 * (0.077)
Sowing date (X_2)	β_2	0.10* (0.07)
Number of ploughings (X_3)	β_3	0.016 (0.11)
Degree of infection (X_4)	β_4	0.05* (0.002)
Number of insufficient irrigations (X_5)	β_5	-0.23*** (0.07)
Agricultural income (X_6)	β_6	-0.13 (0.11)
Years of experience (X_7)	β_7	0.153*** (0.05)
Off-farm income (X_8)	β_8	0.797*** (0.18)
$\delta^2 s = \delta^2 v + \delta^2$	$\delta^2 s = \delta^2 v + \delta^2$	- 0.02** (0.01)
$\gamma = \delta^2/\delta^2 s$	$\gamma = \delta^2/\delta^2 s$	0.97*** (0.16)
Mean efficiency		0.733
Log likelihood function		39.28

Values in parenthesis are the corresponding standard errors.
*, ** and *** = significant at 0.1. 0.05 and 0.01 levels of probability, respectively.
Source: estimated by model 2008.

The coefficient of farmer's experience has a positive sign indicating that farmer's efficiency, and hence wheat output increases with increase of farmer's experience. The negative coefficient of off-farm income indicates that off-farm income has negative effects on wheat production. This may be due to two main reasons: First, the farmer who is engaged in an off-farm job has little time, compared with others, to look after wheat. Second, the off-farm income is mostly used for consumption purposes rather than reinvested in wheat production. This is why off-farm income reduces farmer's efficiency and accordingly wheat production.

As indicated in the theory, the estimated δ coefficients are associated with the explanatory variables in the model to reflect the inefficiency effects. The gender, land tenure and land preparation variables have significant negative coefficients, while marital status and farm location have significant positive coefficients (Table 2). Other variables coefficients are not significantly different from zero at any acceptable level. The negative gender coefficient indicated that the inefficiency decreased when the farmer was a male. In other words, male farmers are more efficient than female farmers. The negative coefficient of land tenure indicates that land owners are more efficient than land renters. This is natural as land owners are more careful about their lands relative to land renters. The negative coefficient of land preparation implies that late land preparation decreases production efficiency. The positive coefficient of marital status indicates that married tenants are more efficient than single tenants. This may be due to the fact that married farmers could have help from wives and children. The coefficient of farm location shows that farmers who are located at the tail of the irrigation canal are more inefficient than farmers who are located at the head of the irrigation canal. This is natural because farmers located at the head are in position to have sufficient irrigation than farmers at the tail of the irrigation canal.

Table 2. Wheat production inefficiency model

Variable	Parameter	Estimate
Constant (Z_0)	Z_0	1.74 (0.76)
Gender (Z_1)	Z_1	-1.33** (0.51)
Age (Z_2)	Z_2	-0.0001 (0.006)
Marital starts (Z_3)	Z_3	0.445** (0.22)
Education level (Z_4)	Z_4	-0.004 (0.05)
Family size (Z_5)	Z_5	0.03 (0.04)
Land tenure (Z_6)	Z_6	-1.13*** (0.32)
Harvest date (Z_7)	Z_7	-0.06 (0.15)
Land preparation date (Z_8)	Z_8	-0.52*** (0.135)
Farm location (Z_9)	Z_9	0.13* (0.08)

Values in parenthesis are the corresponding standard errors.
*, ** and *** = significant at 0.1. 0.05 and 0.01 levels of probability, respectively. Source: estimated by model 2008.

CONCLUSIONS

The Gezira scheme is working at 73% of its maximum capacity at the current levels of production inputs and technology, i.e. wheat production could be increased by 27% at the same levels of inputs had farmer been technically efficient. The area of wheat, sowing date, degree of infection with diseases, insufficient irrigation and farmers' experience are the main factors determining wheat production in the Gezira scheme. The off-farm income has negative effects on wheat production because of the time contradiction with some important agricultural operations. The gender, land tenure, land preparation, marital status and farm location with respect to the irrigation canal are the main socioeconomic factors associated with the inefficiency effects of wheat production in the Gezira scheme.

REFERENCES

Ahmed, A.E. (2004). Economic analysis of the irrigated cotton production constraints in Sudan: A case study of Gezira scheme. *Farming and Rural System Economics*. Margraf Publisher, Gmbh, Germany.

Aigner, D.J.; Lovek, C.K. and Schmidit, P. (1977) Formulation and estimation of stochastic frontier production functions. *Journal of Econometrics* 6, 21-37.

Bank of Sudan (2006). Annual reports. Khartoum, Sudan.

Battese, G.E. and Coelli, T.J. (1988). Prediction of firm level technical inefficiencies with a generalized frontier production function and panel data. *Journal of Econometrics* 38, 387-399.

Battese, G.E. and Corra, G.S. (1977). Estimation of the production frontier Model: with application to the pastoral zone of Eastern Australia. *Australian Journal of Agricultural Economics* 21,196-197.

Coelli, T.J. (1996). A Guide to frontier version 4-1: A computer program for frontier production functions estimation. Cepa Working paper 96/07, University of New England, Australia.

Eisa, A.H. and Al-Feel M.A. (2001). Groundnut shared tenancies and farmers' allocative efficiency in Rahad Agricultural Scheme. *University of Khartoum Journal of Agricultural Sciences* 9 (1), 127-135.

EIU (1998). Country profile- Sudan. Economist Intelligence Unit (EIU). London, U.K.

Faki, H. H. (1996). Wheat production and improvement in Sudan. Proceedings of the National Research Review Workshop, Wad Medani, Sudan.

Farrell, M.J. (1957). The measure of production efficiency. *Journal of Royal Statistical Society* A 120, 235-281.

MOAF (2007). Agriculture in Sudan, Field Crops, Wheat. Ministry of Agriculture and Forestry. www. Sudagric. Gov.8dl.

Russell, N.P. and Young T. (1983). Frontier production functions and the measurement of technical efficiency. *Journal of Agricultural Economics* 34, 139-150.

Sharaf Eldin, N. (1993). Seed dressing for aphid control. Proceedings of the 1992 Nile Coordination Conference, Khartoum, Sudan.

Sudagric (2002). Large irrigated agricultural Schemes. Internet on line: www. sudagric.net\largirrig.htm.

الكفاءة الفنيه لإنتاج القمح في مشروع الجزيرة*

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المستخلص: هدفت هذه الدراسة إلى قياس الكفاءة الفنية لإنتاج القمح فى مشروع الجزيرة وتحدي أهم العوامل الاقتصادية و الإجتماعية المحددة لهذه الكفاءة باستخدام نموذج منحنى الإنتاج العشوائى الممكن (Stochastic production frontier model). جمعت البيانات الاولية من عينة عشوائية من 100 مزارع من قطاع ود المنسى فى مشروع الجزيرة، والبيانات الثانوية من مصادر مختلفة ذات العلاقة. أظهرت النتائج أن متوسط الكفاءة الفنية فى مشروع الجزيرة يعادل 0.73 مما يعنى أن المشروع ينتج 73% من الانتاج الممكن فى ظل المستوى الحالى لمدخلات الإنتاج و التقانة المستخدمة. وبمعنى أخر فإنه يمكن زيادة إنتاج القمح بمقدار 27% وبنفس مستوى المدخلات إذا تم استخدامها بالكفاءة المطلوبة. أظهرت النتائج كذلك أن 97% من التذبذب فى إنتاج القمح يرجع الي اختلافات فى الكفاءة الفنية للمزارعين ولا ترجع للطبيعة العشوائية للإنتاج الزراعى الخارجة عن تحكم المزارع. كما أظهرت النتائج أن المساحة المزروعة، وتاريخ الزراعة، ومعدل الاصابه بالإمراض والآفات و عدد الريات غير الكفوءة، و خبرة المزارع، تمثل أهم العوامل المحددة لإنتاج القمح في مشروع الجزيرة. أوضحت النتائج أيضا أن الدخل غير المزرعى له آثار سالبة على إنتاج القمح وذلك للتضارب في التوقيت بين العمل خارج المزرعة وبعض العمليات الزراعية المهمة. أما نموذج عدم الكفاءة فقد أظهر أن النوع ، وملكية المزرعة، وإعداد الأرض، والحالة الاجتماعية للمزارع وموقع الحيازة من قناة الري، تمثل أهم العوامل المحددة لكفاءة مزارع القمح فى مشروع الجزيرة.

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