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Technical Efficiency in Agriculture in Ghana-Analyses of Determining Factors

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Abstract

The paper sought to estimate technical efficiency in Ghana's agricultural sector and more importantly, investigate the factors that influence the estimated technical efficiencies. Using data from 1976-2007, the results showed a decreasing returns to scale in Ghana's agriculture. Land is negatively inelastic showing over use of the factor. Technology variables, fertiliser and tractor and combines are positively related to output. Whilst fertiliser is elastic, tractor and combines is inelastic. The level of inefficiency is 21% with decreasing returns to scale. The SFA specification is the appropriate model, indeed, superior to OLS. None of the hypothesised variables to explain technical efficiency were statistically distinguishable from zero. The negative sign for land requires decrease in the use of land relative to other inputs. This calls for increase in the use of other variables. The insignificance of the TE effect variables suggest that these variables may be inappropriate in explaining TE in the case of Ghana. Other variables may have to be explored.

Keywords: technical efficiency, agriculture, Ghana, determinants

1. **Introduction**

1.1 Background

The traditional roles of agriculture include provision of food security, supply of raw materials for industry, creation of employment and generation of foreign exchange earnings. Additionally, agriculture is recognised for social stabilisation, buffer during economic shocks, support to environmental sustainability, and cultural values associated with farming. Furthermore, agriculture is acknowledged to impact on poverty reduction more than other sectors (MOFA, 2007). In fact, Bogetic *et al* (2007) and Coulombe & Wodon (2007) provide evidence that the poverty rate in Ghana fell from 51.7% in 1991-1992 to 39.5% in 1998-1999 and 28.5% in 2005-2006. In the light of the foregoing agriculture remains strong in Ghana. The sector still employs 54% of Ghana's population (UNCTAD, 2011) and contributes 10% to non-traditional exports despite a decline in the sector's contribution to Ghana's GDP from 40% in 2000 to 30% in 2010 (MOFA, 2011).

Agricultural production which is largely rainfed (only 0.2% of irrigated land) provides food for the inhabitants. The 2010/2011 food balance sheet revealed that the country recordered food surpluses; 0.075m metric tonnes (MT) of legumes, 0.69m MT of cereals and 8.29m MT starchy staples (MOFA, 2011). The main legume crops grown are groundnuts, cowpea and soyabean. Cassava, yam, plantain and cocoyam constitute main starchy staple crops produced in Ghana. In respect of cereal production, the main crops include maize, sorghum, rice and millet. Aside of food, Ghana produces industrial crops; mainly cocoa, coffee, rubber, sheanut and oil palm for export. The livestock sub-sector is dominated by poultry on both small and medium scale. The rest are the production of cattle, pigs, sheep and goats. The fisheries sub-sector, the smallest in terms of GDP contribution is largely marine. There is however, a growing attraction of fish culture especially, tilapia within Ghana's main river, the Volta.

The focus of Ghana's Agricultural Development Agenda emphasises the sustainable utilisation of all resources and commercialisation of activities in the sector with market-driven growth in mind and targets some commodities for food security and income diversification, especially of resource poor farmers. Additionally, greater engagement of the private sector and collaboration with other partners are court to facilitate implementation of agricultural policies (MOFA, 2007). Moreover, enhancement of productivity of the commodity value chain, through the application of science and technology, with environmental sustainability is emphasised.

The focus on enhancement of productivity brings to the fore the issue of productive efficiency. Technical efficiency (TE) measures the difference between the ideal production possibility curve (PPC) (in this case for a country) and the actual level of performance (of the country) relative to the PPC. This Farrell (1957) described as output-oriented efficiency. From a cross-sectional perspective, the concept involves assessing each farm's production performance compared to a best-practice input-output relationship or frontier. The best-practices production frontier is established by the practices of the most efficient farmer(s). Thus, the deviation of the individual farm from the frontier measures technical efficiency (TE). From time series perspective and of a country, the best-practice frontier is the potential output for the best practice year. Thus, the TE in that case, is the gap between the actual output for any particular year and the potential output of the best-practice year.

1.2 Problem Statement

Agriculture is predominantly practised on smallholder, family-operated farms using rudimentary technology to produce about 80% of Ghana's total agricultural output. Despite contributing 30% to GDP, agricultural land-use constitutes 50% of total land use in Ghana (MOFA, 2007) and employs more than 50% of Ghana's population (UNCTAD, 2011). Following Ghana's agricultural development objective of enhancing productivity, the substantial physical and human resources employed in agriculture, what is the factor productivity in Ghana's agricultural sector? How efficient is agricultural production? What factors explain efficiency in the agricultural sector?

1.3 Objectives

The paper seeks to estimate technical efficiency in the agricultural sector and determine the factors that influence the estimated technical efficiencies.

1.4 Relevance

Determinants of the estimated technical efficiencies have been investigated in several cross-sectional studies, however, rarely in the case of time series work (Miljkovic and Shaik, 2010), is TE investigated. Recently, Djokoto (2012) investigated the technical efficiency of agriculture in Ghana but failed to identify the factors that explain the estimates of TE. Yet, Clark (1957), in his discussion of Farrell's paper in 1957 was unsurprised about the need for economists to look for social and other factors that lie behind technical efficiency estimates of agriculture.

1.5 Organisation of study

The rest of the paper is composed into four main sections. Section 2 presents review of literature pertinent to the title of study. Section 3 presents data and methods of analyses. Section 4 contains the results and accompanying discussions. Reporting the research concludes in section 5 with the associated recommendations.

2. Literature Review

2.1 Theoretical review

The need to assess efficiency of production has long engaged the attention of economists (Debreu, 1951) and statisticians (Farrell, 1957). M. J. Farrell at a meeting of the Royal Statistical Society of UK presented his seminal work on efficiency and its measurement in agriculture. From then, there have been several developments in the field of efficiency and its measurement particularly in agriculture.

There are four major approaches to measure efficiency (Coelli *et al*., 1998). These are the non-parametric programming approach (Charnes *et al*., 1978), the parametric programming approach (Aigner and Chu, 1968; Ali and Chaudry, 1990), the deterministic statistical approach (Afriat, 1972; Schippers, 2000; Fleming *et al*., 2004) and the stochastic frontier approach (Aigner *et al*, 1977).

Due to the inherent stochasticity involved in SFA (outlined in the methodology section), it is preferred for assessing efficiency in agriculture (Coelli, 1995; Ezeh, 2004). Aigner *et al* (1977) and Meeusen & van den Broeck (1977) independently laid the foundations of stochastic frontier approach (SFA). Kumbhakar & Lovell (2000) and Greene (2004), acknowledged the surge in efficiency studies with extensions to estimate technical change, efficiency change, and productivity change measures using SFA. The distribution of asymmetric component, u (inefficiency) and conditional estimation of inefficiency are examples of additional dimensions of efficiency that has engaged the attention of investigators.

2.2 Empirical review

Milner & Weyman–Jones (2003) studied 85 developing countries over 1980-1989 and concluded that country size was important in explaining aggregate efficiency. A strong positive developmental–efficiency relationship and evidence of a positive impact of trade policy openness and health (measured as average life expectancy at birth in years) on aggregate efficiency exists in developing countries. The conclusions of Iyer *et al* (2008) after investigating 20 OECD countries over 1982-2000 with a stochastic frontier estimation, showed that trade and all foreign investment inflows were found to enhance efficiency. FDI outflows rather exacerbated inefficiency. Productive (economic) efficiency and factors affecting it were evaluated in the Caribbean between 1983 and 1992 by Lall *et al*, (2000). The results from non-parametric programming indicated that efficiency (i.e. pure technical, allocative and economic) measures were lower and more variable in Caribbean than in other Western Hemisphere countries. Using a Tobit regression analysis, they showed that higher levels of private and foreign investments, productive infrastructure, credit availability, education level, and consumption of domestically produced goods had positive impacts on the efficiency measures. On the other hand, higher levels of public expenditure, income tax, and export taxes, and higher inflation rates had negative effects. The study advocated support for the trend towards more open economies (i.e. letting the free market work) and encouraging governments to confine their functions to facilitative/regulatory type roles and to undertaking tasks that are not generally undertaken by the private sector. Following the differing impacts of these factors between Caribbean and Latin America, Lall *et al* (2000) admonished that relatively greater emphasis should be placed on TE factors such as foreign and private investment and developing infrastructure in the Caribbean than in Latin American countries. In studying 16 African countries using data envelopment analysis (DEA), Nkamleu (2004) showed that total factor productivity (TFP) increased. With data covering 1970-2001, the study further showed that the increases in TFP growth in the agricultural sector were due to good progress in technical efficiency rather than technical progress. The region suffered a regression in productivity in the 1970s, and made some progress during the 1980s and 1990s. Another highlight was the fact that technical change had been the main constraint of achievement of high levels of total factor productivity during the reference period in sub-Saharan Africa. On the contrary, in Maghreb countries, technological change had been the main driving force of productivity growth. An institutional factor that explained technical change and TFP change was illiteracy. This was negatively related to the dependent variables.

In a time varying estimation, Sotnikov (1998) showed that average TE of 0.77-0.92 was obtained for the period 1991-1993 and 0.78 for 1995 covering 75 Russian regions. The factors that were statistically significant in explaining TE were road density (particularly in rural areas), number of workers per manager (representing management), manager education and farm size. With exception of manager education, all other factors exerted a negative effect on technical efficiency.

In the case of Brazil, empirical results suggest that technical efficiency is influenced by a number of factors that were not related to the technological choices made by the producers (Igliori, 2005). Environmental conditions, location, transportation network, farm size distribution, and the size of local economies were the main elements explaining technical efficiency variation which ranged between 0.01 and 0.92 with a mean of 0.38.

Mathijs *et al* (2001) used Tobit regressions with farm-specific efficiency scores to show the importance of human capital variables such as education on efficiency. They explained that tackling the problems of missing or imperfect markets for inputs and output and thus reducing related transaction costs is necessary to produce efficiently. They observed that being member of a cooperative or partner of a company affected the efficiency level of family farms positively in the Czech Republic because certain production inputs were more easily accessible. For farm enterprises, producing on contract increased efficiency because such contracts facilitated the adoption of technology and access to credit. In addition, they noted that economies of scope were important as more specialised farms were more efficient. Provision of services to individuals lowered the efficiency level of farm enterprises.

3. Data and Methods

3.1 Model[1]

The model used in the study is specified as:

$$y = f(X)e^{v-u} \quad \text{.......... 1}$$

Following Miljkovic and Shaik (2010) and applying natural logarithm and matrix notation will result in stochastic production frontier model (2).

$$\ln y_t = X_t\beta + v_t - u_t \quad \text{.......... 2}$$

where y_t denotes the output for the year t (t =1, . . . ,N), $\boldsymbol{X}_t$ is a vector of the production inputs as well as a column of ones, $\boldsymbol{\beta}$ is a vector of parameters to be estimated, v_t and u_t are error terms defined

[1] This sub-section draws on earlier work by Djokoto (2012).

below. The frontier production function is a measure of the maximum potential output obtainable. Both v_t and u_t cause actual production to deviate from this frontier. The random variable in the production that cannot be influenced by producers is represented by v_t, is identically and independently distributed (iid) as $N(0, \sigma^2_v)$. The non-negative error term u_t represents deviation from the maximum potential output attributable to technical inefficiency which is independent of v_t. It is also assumed to be identically and independently truncated in t instead of zero (half-normal distribution when $\mu = 0$) as $N(\mu, \sigma^2_u)$. The stochastic terms v_t and u_t are assumed to be uncorrelated.

Modifying Jondrow *et al* (1982), and following Djokoto (2012) the technical efficiency of agricultural production is given by the mean of the conditional distribution of u_t given ε_t as defined by:

$$E(u_t / \varepsilon_t) = \frac{\sigma_u \sigma_v}{\sigma}\left[\frac{f(\varepsilon_t \lambda / \sigma)}{1 - F(\varepsilon_t \lambda / \sigma} - \frac{\varepsilon_t \lambda}{\sigma}\right] \qquad \text{.......3}$$

where $\lambda = \sigma_u / \sigma_v$, $\sigma^2 = \sigma^2_u + \sigma^2_v$, while f and F represent the standard normal density and cumulative distribution functions respectively evaluated at $\varepsilon_t \lambda / \sigma$.

Along with the parameters of the function itself, FRONTIER also estimates the following parameters of the likelihood function:

$$\sigma^2 = \sigma^2_u + \sigma^2_v \qquad \text{and}$$

$$\gamma = \frac{\sigma^2_v}{(\sigma^2_u + \sigma^2_v)} \qquad \text{.......4}$$

Testing the significance of the parameter γ is of interest from the point of view of model specification. It must be in the range 0-1, and measures the share of total variation that is attributed to technical inefficiency. If $\gamma = 0$, it means that $\sigma^2_v = 0$, then, the stochastic production frontier is not a good specification, and the model could alternatively be estimated by ordinary least squares.

The year specific technical efficiency is defined in terms of observed output y_t to the corresponding y^* using the available technology derived from the result of (3) as:

$$TE_t = \frac{E(y_t \mid u_{t,} X_t)}{E(y_t \mid u_t = 0, X_t)} \qquad \text{.......5}$$

Or

$$T.E. = \frac{y_t}{y^*_t} = \frac{e^{(X_t \beta + v_t - u_t)}}{e^{(X_t + v_t)}} = e^{-u_t} \qquad \text{.......6}$$

where y_t is the observed output in year t and y^*_t is the frontier output in year t.

The solution of equation 5 becomes e^{-u_t} so that $0 \le \frac{y_t}{y^*_t} \le 1$. That is, technical efficiency is between 0 and 1. The above transformation constrains the technical efficiency of each year to a value between zero and one, and is inversely related to the inefficiency.

The measure of technical efficiency is thus based on the conditional expectation of (5), given the value of ($v_t - u_t$) evaluated at the maximum likelihood estimates of the parameters $\boldsymbol{\beta}$ where the maximum value of y_t is conditioned on $u_t = 0$ (Battese and Coelli, 1995).

The equation:

$$u_t = Z\delta \qquad \text{...7}$$

was estimated and Z; is a vector of variables that are assumed to influence technical efficiency and δ is a vector of parameters to be estimated. Following Desai (1976), Li & Wahl (2004), and Miljkovic and Shaik (2010), a Cobb-Douglas production function in matrix notation (8) and (7) were estimated jointly in FRONTIER 4.1c (Coelli, 1995).

$$\ln y_t = \beta_0 + \sum_{j=1}^{6} \beta_j X_{jt} + v_t + u_t \qquad \text{...8}$$

where y_t represents total output per annum in constant 1999-2000 US dollars. j is the number of explanatory variables, so that j = (1,2…6), such that X_1 is agricultural land in hectares, X_2 is labour in number of persons, X_3 is fertiliser consumption in tonnes, X_4 is tractor and combines in numbers, X_5 is other agrochemicals in US dollars. X_6 is seeds measured in tonnes. v_t and u_t are as defined earlier.

3.2 Estimation Procedure

Essentially, a two stage procedure is employed. The first involves estimation of TE and the explanatory variables of the estimated TE determined. This may involve estimating a production function to collect TEs which are then regressed on explanatory variables. Lall *et al*, (2000) used this procedure. Fried *et al.*, (1993) provides some reasons for estimating all parameters of the model in one stage. First, this procedure provides more efficient estimates than the two-stage procedure, whereby efficiency scores are obtained and then regressed on explanatory variables. Second, in general, it is hard to distinguish between a variable that belongs to the first stage (production function) and the second stage (explanatory variables of efficiency). Third, in a one-stage model, explanatory variables directly influence the transformation of inputs and efficiency is estimated, controlling for the influence of explanatory variables (z's). The parameter estimates generated from the stochastic production function estimation are themselves important statistics for policy analysis, as they are the basis for estimates of the marginal products and production elasticities of individual inputs (Sotnikov, 1998).

3.3 Data

Below are the details of the variables used for the analysis.

3.1.1 Output

Agricultural production

- Output in 1991-2000 prices of Standard Local Currency (Ghana Cedis) was used. The data was converted to US dollar by multiplying the inverse of the exchange rate (GHC/US$) data obtained from International Financial Statistics (IFS) of the International Monetary Fund (IMF). This resulted in US dollar value of Agricultural production.

3.1.2 Input

- Agricultural land

The sum of area under arable land (land under temporary crops, temporary meadows for mowing or pasture, land under market and kitchen gardens and land temporarily fallow), Permanent crops (land cultivated with crops that occupy the land for long periods and need not be replanted after each harvest, such as cocoa, coffee and rubber), and Permanent pastures (land used permanently for herbaceous forage crops, either cultivated or growing wild).

- Labour

This refers to economically active population in agriculture for each year in Ghana. Economically active population in agriculture was defined as all persons engaged or seeking employment in agriculture, forestry, hunting or fishing sector, whether as employers, own-account workers, salaried employees or unpaid workers. Estimates and projection of the data was available from 1980 to 2050. The 3 years missing data was filled by computing the average annual growth rate for the 1980-2050 and using the average annual growth rate to compute the data points for 1976 to 1979. The economically active population in agriculture is the best proxy of labour input into the agricultural sector, since data on information on differentials in skill levels and the number of hours worked on the farm is not available. The population is numbers of persons.

- Fertiliser

Fertiliser consumption is often viewed as a proxy for the whole range of chemical inputs and more (Mundlak *et al*., 2003). Fertilisers used in Ghana involve different amounts and different types of fertilisers. Following other studies (Hayami and Ruttan, 1970; Rao *et al*., 2003), the sum of nitrogen (N), potassium (P_2O_2) and phosphate (K_2O) expressed in thousands of tons, that is contained in the commercial fertilisers consumed should be used as measure of fertiliser input. However, data of this measure was available only 2002 to 2008. As a result total consumption of all fertilisers was used. Fertiliser was measured in tonnes.

- Tractors and Combines

This variable excludes hoes, cutlasses and bullock ploughs which are important machinery for farming in Ghana. However, in the absence of such secondary data number of tractors, which refer to total wheel, and crawler tractors (excluding garden tractors) used for agricultural production and combine harvesters are employed to represent machinery capital. Tractors and combines were measured in numbers.

- Agrochemicals

Despite the assertion of Mundlak *et al* (2003), availability of data on agrochemicals specifically pesticides, herbicides and so on used in agricultural production are included as additional inputs. This computed as import plus production minus exports equals consumption, This computation was necessitated because query of FAOSTAT for consumption for Ghana yielded null set elements. Agrochemicals were measured in US dollars.

3.1.3 TE effect variables

The variables explored are land area cultivated per agriculture employee, per capita consumption of domestic food production, changes in net agricultural capital stock and agricultural merchandise exports.

-Land area cultivated per agriculture employee

In the absence of data on land holding, this variable is used as a proxy. This will be interpreted as average land area worked-on per person employed in agriculture. The land area excludes water bodies (for fishing) but includes pastures. The variable is computed as land area cultivated divided by economically active agricultural labour force (ha/person).

-Per capita consumption of domestically produced food

This was computed as domestic production less export divided by population and expressed in kilogramme per person. It is expected that increased consumption of domestically produced food improves efficient use of productive capacity and stimulates use of improved technology, thus, improving efficiency.

-Road infrastructure

Data on percentage of roads paved was obtained from WDI. This was augmented with data from Ministry of Roads and Highways (MR&H) Ghana Road Condition Report. Missing data were filled by interpolation and extrapolation. The percentage of roads paved signal some semblance of good condition. It is expected that good roads will promote efficiency as they will facilitate flow of inputs, produce and persons. The flow of produce to market centres will intend create cash for farmers who will then invest these in productive resources to increase efficiency.

- Changes in net agricultural investment stock.

FAO recently published data on composition of agricultural capital stock. The changes were computed as the current year’s net capital stock less previous year’s net capital stock. The changes in stock are considered as flow. This variable may be construed as investment in infrastructures specific to agriculture and is expected to improve output given labour and land. Therefore, a positive sign is expected with technical efficiency *a priori*. The data covers 1975 -2007. However, with the computation of the difference, there a loss of data point of one year. This will thus constrain the time series for the whole analysis to 32 years; 1976-2007.

- Agricultural exports

Agricultural merchandise exports computed in US dollars was used as proxy for market of locally produced agricultural produce. It is expect to increase income of farmers. This increased income should make it possible to procure technology for production to increase efficiency.

Unless otherwise stated all data was obtained from FAOSTAT (http://faostat.fao.org) system of statistics used for dissemination of statistics compiled by the Food and Agricultural Organisation.

4. Results and Discussions

4.1 Production Function

The statistical significance of gamma shows that SFA estimation is appropriate. The natural logarithm formulation of the production function implies that the coefficients are elasticities. All production function inputs are positive except land. And all inputs are statistically significant (at least at 10% significance level) except other agrochemicals and seeds (Table 1). Land use is negative and statistically significant at 1%. This indicates that land in Ghana's agriculture is over used. A decrease in land of 1% will induce 2.49% increase in output. This result agrees with Djokoto (2012) who estimated stochastic frontier model for Ghana with data spanning 1961 to 2010. Labour and fertiliser were both elastic. The positive and significant sign of the labour variable may be explained by the drift of the population to urban areas in a predominantly traditional agricultural system. Though positive, tractor and combines were inelastic. Clearly, the inputs that are capable of influencing Ghana's agriculture are land, labour and fertiliser. Increase in the use of labour, fertiliser and tractor and combines will increase the productivity of land. Tractor and combines as well as fertiliser constitute technology. Hence, enhanced technology holds key to improving agriculture in Ghana.

The return to scale is 0.19811. This is less than 1 hence there is decreasing returns to scale. This is in sharp contrast to Djokoto (2012) who found increasing returns to scale. The difference may be attributable to duration of the study. Whilst his data covered 1961-2010, the data for this study covers 1976 to 2007. The mean technical efficiency is 79%, similar to 86% reported by Djokoto (2012) and higher than 38% for Brazil (Igliori, 2005).

4. 2 Technical efficiency effects

Turning to main focus of the paper, the technical efficiency effects, two characteristics, percentage of roads paved and proportion of domestically produced food consumed were positively related to technical efficiency. Whilst, land cultivated per agricultural labour, net investment and agricultural exports are negatively related to technical inefficiency. Indeed, none of the variables hypothesised to explain TE in Ghana's agriculture were statistically significant. The insignificance of the roads paved is contrary to the findings of Sotnikov (1998) and Lall (2000) but the negative sign conforms. The insignificance may be attributable to the nature of the roads variable. The variable includes trunk roads but excludes feeder roads. The data though not the most appropriate was the available data so was used. Since agriculture in most developing countries (including Ghana) is a rural phenomenon (World Bank, 2008) the coverage and state of feeder roads would have influenced TE better. Suffice it to say that the sign was positive indicative of seeming increased percentage of roads paved with technical efficiency. Land worked per agricultural labour is a proxy for farm size. This was negatively related to TE. The sign conforms to the findings of Sotnikov (1998). The statistical insignificance disagrees with the findings of Sotnikov (1998) and Igliori (2005). In respect of domestically produced food, the sign agrees with the findings of Lall (2000) but diverges with the statistical significance. Agricultural exports are considered as a market avenue such that increased exports will boost incomes that can be applied to technology. The negative and statistical significance is rather surprising and diverges with the findings of Iyer (2008). From the foregoing, none of the variables constructed and hypothesised to influence TE have been effective.

5. Conclusions and Recommendation

5.1 Conclusions

The paper sought to estimate technical efficiency in Ghana's agricultural sector and more importantly, investigate the factors that influence the estimated technical efficiencies. Using data from 1976-2010, the results showed a decreasing returns to scale in Ghana's agriculture. Land is negatively inelastic showing over use of the factor. Technology variables, fertiliser and tractor are positively related to output. Whilst fertiliser is elastic, tractor and combines is inelastic. The level of inefficiency is 21% with decreasing returns to scale. The SFA specification is the appropriate model, indeed, superior to OLS. None of the hypothesised variables were statistically indistinguishable from zero.

5.2. Recommendations

The negative sign for land requires decrease in the use of land relative to other inputs. This calls for increased use of other variables. There is the need to support technology such as fertilisers and equipment such as tractors and combines to increase agricultural production. The use of increased use of these technologies will increase land productivity leading to decreased land use in the presence of increased output.

The stack contrast in of returns to scale to that of Djokoto (2012) also for Ghana requires further investigation. This will establish whether change in time span could result in significant switches in returns to scale measures. The insignificance of the TE effect variables suggest that these variables may be inappropriate in explaining TE in the case of Ghana. Other variables may have to be explored.

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Appendix

Table 1. Estimates of Stochastic Production Function and Technical Efficiency Estimates
Dependent Variable: Value Added Agriculture (US) in natural logarithm

Variables (All in natural logs)	Parameters	Estimates
Constant	β_0	31.4419***
Agricultural land in (hectares) (X_1)	β_1	-2.4889***
Labour in (number of persons) (X_2)	β_2	1.2214**
Fertilizer consumption (tonnes) (X_3)	β_3	1.1604*
Tractor and combines (numbers) (X_4)	β_4	0.09668**
Other agrochemicals (US dollars) (X_5)	β_5	0.10654
Seeds (tonnes) (X_6)	β_6	0.10199
Returns to Scale	0.19811	
Mean Technical Efficiency	0.79	
Technical Effects Coefficients		
Constant	δ_0	-0.15234
Land worked per Agric. Labour (Z_1)	δ_1	-0.32397
Net Investment in Agric. (Z_2)	δ_2	-0.042741
Proportion of domestically produced food consumed (Z_3)	δ_3	0.30918
Percentage of roads paved (Z_4)	δ_4	0.12840
Agricultural Exports (Z_5)	δ_5	-0.05740
Variance Parameters		
Sigma squared	σ^2	0.05673**
Gamma	$\gamma = \sigma^2_u / \sigma^2_s$	0.9999***
Log likelihood function	15.6747	
LR test on one sided error	8.5934	

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