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Assessing the technical efficiency of commercial egg production in Tanzania for improved livelihoods

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This study examined the productivity and technical efficiency (TE) of egg production in Tanzania under the intensive system. A multistage random sampling procedure was employed for selecting 80 respondents from two districts; Kibaha and Ilala. This study utilizes the most recent developments in stochastic frontier modeling as specified for a one-step process in Limdep software. Results indicated that the mean TE of egg production is 64%, ranging from 4 to 90%. Egg production was in the rational stage of production (stage II) as depicted by the returns to scale (RTS) of about 1.3. Thus, there is room for improving TE, which will raise net returns of egg production enterprises, hence, improving livelihoods of farmers and their families.

Key words: Technical efficiency, intensive, egg production, stochastic frontier, Tanzania.

INTRODUCTION

About 94% of the total chicken population in Tanzania is kept in villages and in peri-urban areas under traditional free range system, in most cases owned by women (MAFC, 2008). The traditional poultry system is the largest, supplying more than 90% of poultry meat and eggs consumed in rural areas, and 20% of the same are consumed in urban areas. Despite the predominance of local chicken in Tanzania, Paul et al. (1990) argues that production of layers is comparatively a better source of earning cash, especially in urban and peri-urban areas because it offers higher net returns.

Since the introduction of commercial poultry farming in Tanzania during the 1980s, visible growth in the production of layers has been observed. Small and medium enterprises have increased the numbers of layers from 27 million in 2001 to 38 million in 2008 while the commercial stock increased from 20 million to 25 million. On average, 5.5 million hatching eggs and one million day old chicks are imported annually to produce a total of 25 million day old chicks for commercial purposes (MLD, 2008). This figure is low compared to the actual requirement of 60 million day old chicks per year. Egg production has increased from 790 million in 2002 to 1.8 billion in 2006 (Msami, 2008). The increase is largely due to sensitization on good poultry husbandry practices by farmers and increased use of thermo stable vaccine to control the New Castle Disease vaccine (MLD, 2008). The per capita consumption of eggs has also increased from 23 eggs in 2002 to 50 eggs in 2008 per person per year. Although, the production of eggs has grown rapidly (about 2.5 million eggs/year), still there is a big gap between the demand and supply in the country. Meanwhile, the per capita consumption of eggs in Tanzania at 50 eggs/capita/year is quite low, compared with 106 eggs per person per year for Africa and 190 for high income countries (Gueye, 2004). The rising demand for eggs calls for more investments in the intensive layer production and the poultry industry as a whole. This improvement could further be sustained with a proper analysis of the technical efficiency (TE) of egg production so that net income increases, thereby contributing to reduce poverty.

It is important to assess the TE of poultry farms especially now that the government is promoting

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commercial oriented agricultural production as declared under the Agricultural Sector Development Programme (ASDP) and Kilimo Kwanza (URT, 2001, 2009). Technical efficiency becomes a critical factor for decision making in management and production systems because the cost of production is closely related to the productivity and TE of the farm. Knowledge on the efficiency of a farm can help to identify productivity gaps, including those related to socio-economic characteristics and management practices, which can subsequently be improved. Such knowledge should be used by extension workers for advising farmers to improve both the technical and economic aspects of their enterprises.

This study was conducted in Kibaha district, Pwani region and Ilala district, Dar-es-Salaam region where there is a concentration of poultry farmers to feed the city of Dar-es-Salaam, currently estimated to accommodate over three million inhabitants. Dar-es-Salaam is the commercial center of Tanzania and hence the largest market for almost all agricultural commodities in the country. It is estimated that the city consumes about 303,054 eggs per day on average, compared to only 15,700 in Arusha, 28,730 in Mwanza and 64,118 in Mbeya, the other cities in Tanzania (Msami, 2008). Considering the difficulty of transporting eggs over long distances (in the absence of properly refrigerated and cushioned vehicles), most of the poultry farmers in Tanzania operate close to their targeted markets. In Ilala district, the suburb of Kitunda is famous for producing eggs, ferrying over 350,000 eggs to the city center daily mostly by bicycle or using small pick up trucks (Msami, 2008). Kibaha town, which lies about 40 Km from the city center, along the highway to Zambia, is also famous for egg production to feed the city. The number of egg producers in Kibaha and Ilala districts is estimated to be around 8,333 and 11,160, respectively. This means, the poultry sub-sector plays an important role in providing for the livelihoods to over 18,000 families. Any information, which would improve the productivity of these poultry farms, if used by the extension services and the farmers, would contribute to improving farmers' incomes thereby contributing to the goals of the national strategy for growth and poverty reduction, popularly known by its Kiswahili acronym (MKUKUTA), and the millennium development goals (MDGs).

Often, yield defined in terms of eggs produced per laying period, is used as a measure of productivity in layers. But, this masks the reality regarding the efficiency of using inputs in the production system. Technical efficiency has been used for more rigorous economic analysis in order to identify specific areas of intervention to improve the performance of production systems. This study used TE to assess the performance of poultry farms in the study area, in order to recommend strategies for improvement.

The main objective of the study is to assess productivity and measure the TE of producing eggs under the intensive production systems in urban and peri-urban areas of Ilala district in Dar es Salaam region and Kibaha district in Pwani region, and determine factors contributing to the gap in productivity potential. The study's specific objectives include:

1. To estimate the responsiveness of yield (value of eggs produced per annum per unit of variable input) to the main factors of production by estimating the elasticity of production of the inputs;
2. To estimate the frontier production function and determine levels of technical efficiency for each egg producing farms in the sample drawn from Ilala and Kibaha districts;
3. To evaluate the relationship between technical efficiency and selected farm characteristics.

METHODOLOGY

Conceptual framework

The level of TE of a particular farmer is characterized by the relationship between observed production and some ideal or potential production (Greene, 1993), often measured as a ratio between the output of a particular farmer and the maximum possible output obtainable (frontier) using a given set of inputs under a given technology. The gap can be closed if the limiting technical and socio-economic factors are identified and addressed. This study sought to identify these limiting factors in order to suggest areas of focus for improvement.

Analysis of the poultry farms in the study area shows that a small scale poultry farm as having up to 2,000 birds; a medium scale farm having between 2,001 and 4,999 birds and a large scale farm has above 5,000 birds. The deep litter system is used by all the farmers in the sample. They also almost exclusively buy feed, medicine and feed supplements from similar sources or their outlets. It is therefore, safe to assume that they all use very similar technology for egg production. In the absence of experimental data, the study used the performance of the best farmers in the sample to define the frontier against which the performance of all the other farmers was compared.

Primary data for the study were collected between October and November 2007. First, Ilala and Kibaha districts were purposively selected based on the prominence of egg production relative to other districts in the vicinity of Dar-es-Salaam. The second stage involved a multistage sampling procedure in which two divisions were selected from each district, and two wards from each division. Then, 80 farmers (40 from each district) were randomly selected from the wards. Data was collected using a structured questionnaire, obtaining information on output, inputs and key economic and socio-economic variables as subsequently defined by the empirical models.

Analytical model

A stock of layers is normally raised for 18 to 24 months before it is replaced. Using data from sampled farmers, a stochastic production frontier was estimated to compute the TE of each farmer. Subsequently, the computed TE of each farmer was regressed against a set of socio-economic factors to identify the most limiting variable in the production system. A production function was used to define the stochastic production frontier as given in general form in Equation 1:

$Y_i = f\{S, F, C\ldots\}$ (1)

where; Y_i = total value of eggs produced over 24 months for the i^{th} respondent; S = average value for stock of chicken over 24 months; F = total cost of feed used for production over 24 months; C = total cost of all the other (non-feed) inputs over 24 months.

A rational producer strives to maximize profit by maximizing output (Y) while minimizing cost (F + C), thus obtaining economic efficiency. To establish the production frontier, a Cobb-Douglas type translog functional form with constant elasticity of supply (CES) was used to estimate parameter estimates of Equation 1, as derived further in Equations 2 to 4. A stochastic production frontier is based on the premise that a production system is bounded by a set of smooth and continuously differentiable concave transformation functions for which the frontier is the limit to the range of all production possibilities given the technology and the set of inputs used. Following from Zaibet and Dharmapala (1999), the multiplicative form of the production function is given in Equation (2):

$$y_i = b_0 \prod x_{ij}^{b_{ij}} e^{\varepsilon_{ij}} \quad (2)$$

where: y_i = output for the i^{th} respondent; for i = 1, 2, ………, n; x_{ij} = the j^{th} variable input for the i^{th} respondent; for i = 1, 2,., n and j = 1, 2, ..k; Π = a steady multiplicative symbol; e = natural logarithm; ε = error term for the i^{th} respondent and the j^{th} input; b_0 = a vector of a constant parameter; b_{ij} = a vector of parameter estimates for the i^{th} respondent and the j^{th} variable input.

The log liner transformation of Equation (2) gives Equation (3), which was used for parameter estimation, using frontier regression analysis as described by Kumbhakar et al. (1991):

$$Y_i = \beta_0 + \sum_{j=1}^{k} \beta_{ij} X_{ij} + \varepsilon_i \quad (3)$$

where Y_i = Ln (y_i); β_0 =Ln (b_0); β_{ij} = Ln (b_{ij}); X_{ij} = Ln (x_{ij}); ε_i = Ln (e_i); Ln = natural logarithm

Farell (1957) and Bylee (1991) disaggregated economic efficiency into allocative efficiency and technical efficiency (TE). In a perfectly competitive market, allocative efficiency occurs if the marginal physical product is equal to the ratio of the product price to the corresponding input prices ($\frac{P_x}{P_y} = mpp$). Allocative inefficiency is the failure for a farm to meet the conditions for profit maximization. Meanwhile, TE is defined as the ratio of the observed output to the corresponding output on the frontier, as estimated from the composed error term. In estimating the stochastic frontier production function, effects of the socio-economic characteristics of the household on the variation of the dependent variable (Y_i) are often lumped together in the error term, which accounts for the component of variation due to random, unsystematic and unexplained noise. The error term (ε_i) in Equation (3) has two components u_i and v_i such that:

$$\varepsilon_i = v_i - u_i \quad (4)$$

where v_i represents a random error associated with random factors, over which the farmer has no control. It has a zero mean and a variance equal to δ^2_v such that its distribution is given as N $(0,\delta^2_v)$. Meanwhile, u_i represents the inefficiency component of the error term. It is a non-negative half normal random variable truncated at zero, with a distribution given as, N $(0,\delta^2_u)$. However, u_i can also have other distributions such as gamma and exponential. It is associated with farm-specific factors. The mean values of u_i are determined by Equation (5):

$$u_i = \rho_i Z_i \quad (5)$$

where Z_i represents inefficiency variable for the i^{th} respondent; i = 1, 2…, n; ρ_i = parameter estimates for the i^{th} respondent; δ^2_v and δ^2_u are the variances of v_i and u_i respectively.

The inefficiency variables are represented by farm characteristics such as age, marital status, employment status, education of a farmer, family size, sex, location of the farm, access to credit and management because these traits account for performance differences between farmers, some being more inefficient that others.

Equation (3) was estimated using the maximum likelihood method, on the basis of which, the TE of a production function was obtained from the conditional expectation of u_i given ε_i as shown by Zaibet and Dharmapala (1999) and represented in Equation (6):

$$E\left[-ui \;\middle|\; \varepsilon_i\right] = \frac{\delta_u \delta_v}{\delta}\left[\frac{f^*(\lambda\varepsilon_i/\delta)}{1-F^*(\lambda\varepsilon_i/\delta)} - \frac{\varepsilon_i \lambda}{\delta}\right] \quad (6)$$

where δ_u = standard error of u, the random component of the error term; δ_v = standard of v, the inefficiency component of the error term; λ = ratio of the standard deviation of the error terms, ($\frac{\delta_u}{\delta_v}$); f* = value of a standard normal density; F* = value of the distribution function; $\delta^2 = \delta^2_v + \delta^2_u$, components of variance of the error term, and $E\left[-u_i \;\middle|\; \varepsilon_i\right]$ = the conditional mean of u_i given ε_i, which measures expected value of the random component of the error term.

Technical efficiency is measured as the mean of the negative value of the inefficiency component of the error term (-u) or $\sum_i^n (\frac{-u_i}{n})$, also as given by Equation (7) such that $0 \le TE \le 1$:

$$TE_i = \exp\left(E\left[-u_i \;\middle|\; \varepsilon_i\right]\right). \quad (7)$$

This inefficiency component is influenced by many factors which are discussed next and their effect is determined subsequently.

Empirical estimation

To estimate the stochastic frontier, a two step process was followed. First, using a linear transformed Cobb-Douglas type production function as derived in Equation (3), the value of eggs produced per farmer over 24 months of production (Y_i) was regressed against independent variables including the cost of production, bird stock size and feed intake as given in Equation (8):

$$Y_i = \beta_o + \beta_1 X_{1ij} + \beta_2 X_{2ij} + \beta_3 X_{3ij} + \beta_4 X_{4ij} + \beta_5 \ln X_{5ij} + (v_{ij} - u_{ji}) \quad (8)$$

where Y_i = value of egg produced over 24 months period (TShs); X_1

Table 1. Categorization of farm size by district.

Category	Kibaha		Ilala		Sample	
	(N)	(%)	(N)	(%)	(N)	(%)
100-2000	28	70	40	100	68	85
2001-4099	8	20	0	0	8	10
2001-4099	4	10	0	0	4	5

Source: Oleke (2008).

Table 2. Descriptive statistics on input use and output (N = 80).

Standard measure of sample	Value of eggs (TShs)	Stock size	Cost of drugs (TShs)	Other operating cost (TShs)	Transport cost (TShs)	Feed intake (Kg)	Feed cost (TShs)	Total cost (TShs)
Mean	56,601,289	1,071.8	563,925.6	3,339,139	440,491.8	38,938.9	10,881,347	15,586,883
Mode	30,960,000	300	713,750.0	7,626,000	120,000	7,118,500	7,118,500	20,262,652
Standard deviation	106,445,285	1,265.5	416,530.3	4,111,895	2,093,954	16,296,275	16,296,275	1,832,590
Minimum	2,314,500	200	33,600	355,800	0	634,000	634,000	119,628
Maximum	753,857,260	6,000	1,592,000	22,650,500	18,602,575	127,342,569	12,7342,569	15,586,883

Source: Oleke (2008).

= cost of drugs (TShs); X_2 = transport cost (TShs); X_3 = feed intake (Kg); X_4 = stock of birds (Number); X_5 = other operating cost (TShs); v_i random errors and u_i represents technical inefficiency effects.

The TE of each respondent was computed as the deviation between the antilog of Y_i and Y_P, (Y_p-Y_i) where Y_p is the maximum potential output obtained by the best performing farmer and Y_i is the output of the i^{th} farmer. Then in the second step, based on Equation (5), using the Limdep software, the maximum Likelihood method was used to assess the effect of various socio-economic factors on the variation of TE. The inefficiency component of the error term (u_i) was regressed against factors that are thought to influence deviation of observed output (Y_i) from the potential output level (Y_p). They are all represented in Equation (9):

$$u_i = \rho_0 + \rho_1 Z_1 + \rho_2 Z_2 + \rho_3 Z_3 + \rho_4 Z_4 + \rho_5 Z_5 + \rho_6 Z_6 + \rho_7 Z_7 + \rho_8 Z_8 + \rho_9 Z_9 + \rho_{10} Z_{10} + \rho_{11} Z_{11} + \rho_{12} Z_{12} + \rho_{13} Z_{13} + \rho_{14} Z_{14} \quad (9)$$

where; Z_1 = location of the farm (Urban = 1, Peri-urban = 0); Z_2 = farmer's marital status (Married = 1, Otherwise = 0); Z_3 = education level of a farmer (years); Z_4 = experience of a farmer squared (squared term); Z_5 = Use of credit (use of credit =1, no use of credit = 0); Z_6 = family size (Number of people); Z_7 = experience of the farm attendant (years); Z_8= level management (represented by the technology for lighting and temperature (a dummy variable: Electricity = 1, charcoal/kerosene = 0); Z_9 = housing type (Concrete walls and iron roof =1, mud walls and iron roof = 0); Z_{10} = farmer's employment (formal employment = 1, no formal employment = 0); Z_{11} = education level of farm attendant (years); Z_{12} = age of the farm attendant (years); Z_{13} = sex of the household head (Male=1, Female=0); Z_{14} = age of a farmer (years), and ρ_o, ρ_1, ρ_2 ,... ρ_{14} = parameter estimates.

FINDINGS AND DISCUSSION

Description of farms

For this study, farms were classified by size according to the number of birds. Boki (2000) classified small farms as having up to 2,000 birds, medium sized farms had from 2,001 to 4,999 birds and large farms had 5,000 birds or more. On average, farms were larger in Kibaha compared to Ilala with mean stock sizes of 624.9 and 518.7 birds, respectively (Table 1). However, for the entire sample, smaller sized farms dominated with a sample mode of 300 birds. About 85% of the poultry farms were small while 10% were medium and only 5% were classified as large. The large and medium sized farms were found only in Kibaha district, which is located further from the city center where there is more room for farm activities.

The value of output per farm over a period of 24 months was obtained by adding cash receipts from the sale of eggs produced, value of eggs consumed by the farmers' households and the value of manure. The mean value of egg produced was 56,601,290 TShs per farm (Table 2), and a mean total cost of 15,586,883 TShs; thus, net returns of 41,014,406 TShs per farm per stock or about 38,696 TShs per bird on average over 24 months. The mean cost of drugs per farmer was 563,927 TShs with a standard deviation of 416,530 TShs while other operating cost had a mean of 3,339,139 TShs with a standard deviation of 4,115,895 TShs in the entire life

Table 3. Respondents' personal characteristics.

Standard measure of the sample		Kibaha	Ilala	Whole sample
Sex	Male (%)	34	52.5	38.5
	Female (%)	66	47.5	61.5
Household size	Mean number of members	7.9	7.7	7.8
Age	Mean age (Farmer)	47.7	37.3	41.3
	Mean age (Attendant)	21.4	35.4	22.4
Marital status	Married (%)	85	95	91
	Single (%)	15	5	9
Educational level	Mean years education (Farmers)	11.4	7.6	7.3
	Mean years education (Attendants)	7.1	6.7	7
Experience	Farmers' experience (years)	7.8	7.4	7.6
Employment	Employed male (%)	66	4	33
	Employed female (%)	37	11	23
	Not employed male (%)	33	96	66
	Not employed female (%)	63	89	77
Quality of housing	Iron roof and concrete wall (%)	97.5	17.5	55.5
	Iron roof and mud walls (%)	2.5	85.5	45.5
Use of credit	Had access to credit (%)	35.2	5	19
	Did not use credit (%)	67.5	95	81
Flock size	Mean number of birds	1,624.9	518.7	1,071.8

Source: Oleke (2008).

of the stock. The study further reveals that on average, farmers incurred transport cost amounting to 440,499 TShs, with a standard deviation of 2,093,954 TShs during the entire life of stock. Feed consumption had a mean of 10,881,347 TShs, constituting the major components of poultry production cost in both study areas, accounting for about 70% of production cost. On average, about 38,939 kg of feed was consumed per farm during the life of stock of bird.

Respondents' characteristics

Information was collected regarding the personal characteristics of the farm managers and the attendants who carry out routine jobs on the farm (Table 3). Some of the information that is relevant for this analysis is presented here. For the sample as a whole, majority of the respondents were women (61.5%). However, there was male dominance in Ilala, where men constitute 52.5% of the respondents compared to 47.5% for women. In Kibaha, women constitute 66% of the respondents compared to 34% for men. The mean household size for the entire sample was 7.8 people being 7.9 in Kibaha and 7.7 in Ilala. The distribution of respondents by age gave a mean of 41.3 years for farmers and 22.4 for farm attendants. Farmers tended to be younger in Ilala at 37.3 years on average compared to 45.7 years in Kibaha. On the other hand, farm attendants were older in Ilala at a mean of 35.4 years relative to 21.4 years in Kibaha. Both the oldest farmer (61) and the youngest (23) were found in Kibaha district. Majority of the respondents (91%) were married, more so in Ilala (95%) compared to Kibaha (85%). The educational level of both farmers and attendants was low. Farmers had 7.3 years of formal education on average being higher in Kibaha (11.4 years) compared to Ilala (7.6 years) with a minimum of 7 years in both districts. The mean education of attendants was lower (7 years) but not significantly different from that of farmers. The attendants in Kibaha tended to be more educated (7.1 years) compared to Ilala (6.7 years), and the education of attendants in Kibaha was lower than that of their employees while the educational difference between attendants and farmers in

Table 4. The production frontier and technical efficiency.

Variable	Proxy parameter	Expected sign	Estimated coefficient	Standard error	t- Value
Production frontier parameters(Equation 8)					
Constant	β_0	+/-	7.18**	2.05	2.80
Cost of drugs	β_1	+	0.02	0.12	0.67
Transport cost	β_2	+	0.06	0.10	0.09
Amount of feed	β_3	+	0.37**	0.23	1.21
Stock size	β_4	+	0.54***	0.15	3.25
Operating cost	β_5	+	0.26*	0.16	1.75
Variance parameter (Equation 8)					
Ratio of Standard error changes (δ_u/δ_v)	λ		17.65*	996.40	
Sum of standard error changes ($\delta_u + \delta_v$)	δ		10.18*	573.89	
Variance of inefficiency error (u)	δ_u^2		103.30		
Variance of random error (v)	δ_v^2		0.33**		
Log likelihood function			- 91.18		
Variance ($\delta^2_u/\delta^2_u + \delta^2_v$)	γ		0.99		
Mean technical efficiency	$TE_{(mean)}$		64%		

*** = α = 0.1; ** = α = 0.05; and * = α = 0.001 representing significance levels.

Ilala is not significant. Some of the farm attendants in both districts had no formal education, but the lowest education of farmers in both districts was 7 years.

The respondents had been farming poultry for 7.6 years on average, being slightly higher in Kibaha (7.8 years) than Ilala (7.4 years) with a sample mode of 8 years. Majority of respondents are not employed in the formal sector, implying that their poultry enterprise is probably one of their main sources of livelihood. Only about 33 and 23% of the male and female respondents respectively had other employment. However, in Kibaha, more than half of the male respondents (66%) were employed elsewhere but only 37% of their female counterparts had the same status. In Ilala district, more of the male respondents (96%) were not employed elsewhere compared to 89% of the female respondents. Assessing the quality of the respondents housing, about 55.5% of the respondents had improved houses made of concrete walls and iron roofs but 45.5% had houses were made of mud walls with iron roofs. There is a significant difference between districts on this variable. More than 97% of the respondents in Kibaha had concrete walled houses whereas in Ilala district, more than 85% of the respondents had houses made of mud walls, with iron roofs.

The use of credit for poultry enterprises was low in both districts, but especially in Ilala where only 5% of the respondents used credit during the study period compared to 35.2% in Kibaha and 19% for the whole sample. This can be attributed to a number of reasons including a higher level of education of farmers in Kibaha and a higher mean number of birds raised (1,624.9) nearly three times the mean for Ilala (518.7). Some of these personal characteristics were then used to estimate the production frontier of the technology used by farmers in the study area, hence determine performance differences (technical efficiency) among farmers, and then to identify factors that influence the variation of TE.

The production frontier and technical efficiency

The production frontier was estimated using Equation (8) as previously described, regressing the value of production (y) against a set of variables that influence variation of the dependent variable, using the maximum likelihood analytical model. Table 4 presents a summary of parameter estimates of the production function and the parameters for measuring the degree of variance. Equation 8 was tested and found to be free of multicollearity, heteroskedacity and autocorrelation (Oleke, 2008). The sum of standard errors (δ = 10.18) is significantly different from zero, indicating good fit and correct specification of the model. The value of Gamma ($\Upsilon = \delta^2_u/\delta^2_u + \delta^2_v$) measures the relationship between random variation in the production of eggs and inefficiency in the use of inputs. The computed value of 0.99 implies 99% of the random variation in egg production is explained by inefficiency in resource utilization. Furthermore, a high value of the natural log for the likelihood functions (-91.18), which is always negative, means the observed results were more likely to occur, again implying a high predictive ability of the model.

Table 5. Factor price and marginal value product.

Variable	APP	Elasticity of production	MPP	VMP (TShs)	Factor cost (P_x) TShs
Cost of drugs (X_1)	196.9	0.024	4.72	708	526.1
Transport cost (X_2)	252.1	0.06	15.1	2,265	410.9
Amount of feed (X_3)	2,851.7	0.37	1,055.1	158,265	260.0
Stock size (X_4)	103,606.4	0.544	56,361.8	8,454,270	1000.0
Other operating cost (X_5)	33.3	0.26	8.6	1,290	3,115.0

Source: Oleke (2008).

Most of the variables affecting the efficiency of the production system have parameters that are statistically significantly different from zero. For example, estimates of the ratio of changes in the standard error due to inefficiency to corresponding changes in the error term due to random error (λ = 17.65), implying that variation in output comes more from differences in farmers practices rather than from random variation. This is supported by the variance of the random component of the error term ($\delta_v^2 = 0.33$) being significantly different from zero but relatively small in magnitude, while changes in the variance of the inefficiency component of the error term ($\delta_u^2 = 103.3$) is not significant but relatively large in magnitude. These values indicate the relative magnitude of the variance with the inefficiency effects constituting a larger share. The mean technical efficiency of the production frontier is estimated at 64%.

The sign of the constant and all the independent variables are positive as expected implying that an increase in any of the variables will result in an increase in the value of production. The parameter estimates of the variables represent partial elasticities of production. Changes in the stock size have a highly significant effect on the value production such that if the stock of production increased by 1% the value of production would increase by 0.54%. The amount of feed used by a farmer also has a significant effect at $\alpha = 0.05$, increasing production by 0.37% for every 1% increase in this variable input. The other operating cost of the poultry enterprise also have a significant influence on the value of production (at $\alpha = 0.10$). If the operating cost increases by 1% the value of production would increase by 0.26%. The cost of drugs and transportation has a positive effect on the value of production, but it is not significant. A 1% increase in the cost of drugs and transport cost would increase the value of production by only 0.02 and 0.06%, respectively.

The summation of all the partial elasticities of production with respect to every input is 1.25, representing the total output elasticity or the function coefficient, also referred to as returns to scale. If all factors are varied by the same proportion, the function coefficient indicates the percentage by which output would increase. In this case, it means if all of the variables were to increase by 1%, output would increase by 1.26% representing increasing return to scale. This means there is still room for improving the productivity of poultry enterprises in the study area by increasing stock size, which is consistent with the finding of Nair and Ghadoliya (2000) who reported that larger flocks sizes (>20000 birds) yielded higher returns per bird compared to smaller flocks. The findings also conform to similar findings by Ramrao et al. (2008), who reported that farmers who maintained a flock size of 10,000 layers were able to recover their fixed invested capital from production of layer in about two years compared to those who keep smaller flock sizes. The results also show that for all the factors of production, there is room for improvement because the respective value marginal product is higher than the corresponding factor cost $(VMP > P_x)$, implying there is room for adding more variable inputs (number of birds, feed, drugs, transport) up to the point where $(VMP = P_x)$ as can be seen in Table 5. It seems that the most gain would come from increasing the stock size and the amount of feed. However, in the case of other operating cost, which included labor, water and lighting, the VMP is less than the factor cost implying the need to reduce them down to the profit maximizing point.

Table 6 presents the predicted TE values for each district and for the whole sample. It is evident that the farmers operate within a wide spectrum of TE ranging from 90 to 4% and a sample mean of 64.8% with a standard deviation of 15.8%. Kibaha district exhibited a higher level of TE at 69.8% compared to 59.8% for Ilala (Table 6). The scope of a production frontier measures existing room for improving from the current level of productivity up to the maximum potential. For the sample as a whole, the scope for improvement is 35.2%, being higher in Ilala (40%) relative to 30.2% in Kibaha, which is consistent with relatively better efficiency exhibited by farms in Kibaha.

The effect of socio-economic characteristics on technical efficiency

In the second stage of the study, the TE of each farmer was regressed against their corresponding socio-economic characteristics as derived in Equation 9.

Table 6a. Technical efficiency.

Standard measure of the sample	Kibaha	Ilala	Whole sample
Number of respondents	40.0	40.0	80.0
Mean TE	69.8	59.8	64.8
Standard deviation	11.4	15.7	15.7
Minimum TE	30.0	3.9	3.9
Maximum TE	90.0	80.0	90.0
% Scope	30.2	40.0	35.2

Source: Oleke (2008).

Table 6b. Technical efficiency by farm size.

% Technical efficiency	Farm size						Total	
	100-2000		2001-4999		≥5000			
	(N)	%	(N)	%	(N)	%	(N)	%
<30	5	8.33	0	0	0	0	5	6.25
30-39	2	2.99	0	0	0	0	2	2.50
40-49	1	1.4	0	0	0	0	1	1.25
50-59	9	13.2	0	0	0	0	9	11.25
60-69	30	44.11	2	25	0	0	32	40.00
70-79	20	29.41	4	50	4	100	30	37.50
≥80	4	5.88	2	25	0	0	6	7.50
Total	67	100	8	100	4	100	80	100

Source: Oleke (2008).

Table 7a. Percentage technical efficiency by sex.

Sex	District		Average
	Kibaha	Ilala	
Females	75.0	62.0	68.0
Males	64.0	57.0	60.5
Mean	69.8	59.8	64.8

Source; Oleke (2008).

Results as presented in Table 7a show a condition index of 12.78 and a Durban Watson index of 1.72 indicating the model is free of multicollinearity and autocorrelation. The predictive ability of the model (R^2) is high showing that 78.1% of the variation in TE is attributed to the socio-economic variables presented in Table 7b. A negative sign on an efficiency parameter means that the variable increases TE, while a positive sign reduces TE. All the independent variables are expected to have a negative sign, which implies a positive sign for any quadratic term, as is the case for the farmers' experience. The sign for location (+0.5023) had a positive sign as expected implying that farms that were further from the input and product market would tend to reduce efficiency. Likewise, the quadratic term of the farmer's experience was positive (+ 0.622), implying a negative linear sign. The quadratic term of experience was also positive, which implies that farmers who have been raising layers for more years tend to have higher TE. The remaining parameters were expected to have negative signs, however, exceptions were observed in the case of; attendants' years in business (+0.048), the attendants level of education (+0.0002), the farmers' type of housing (+0.3243) and the farmers' age (+0.0001). These had a positive sign implying that a unit increase in each of the variables would reduce the farm's technical efficiency.

The sign indicate that farm owners ought to provide more supervision to attendants who have worked for them for longer periods and those who are more educated because they may gloss-over the job they are assigned to do since they command more trust from the farm owner. As regards the farmers housing type where farmers with better houses and farmers who are older

Table 7b. Determinants of technical inefficiency.

Variable	Proxy coefficient	Expected sign	Estimated coefficient	Standard error (SE)	t - Value
Constant (Z_0)	ρ_0	+/-	-1.0222*	0.0323	34.21
Location (Z_1)	ρ_1	+	+ 0.5023***	0.3043	1.67
Marital status (Z_2)	ρ_2	-	- 0.9813***	0.4314	22.22
Education of farmer (Z_3)	ρ_3	-	- 0.5117**	0.0244	0.74
Farmers years in business (squared) $(Z_4)^2$	ρ_4^2	+	+ 0.622**	0.2778	2.27
Use of credit (Z_5)	ρ_5	-	- 0.3308*	0.1803	1.84
Family size (Z_6)	ρ_6	-	- 0.0014*	0.0016	-1.82
Attendant years in business (Z_7)	ρ_7	-	+ 0.048	0.974	0.12
Lighting in poultry house (Z_8)	ρ_8	-	-0.1656	0.5689	-0.28
Farmers' house type (Z_9)	ρ_9	-	+ 0.3243	0.1512	1.35
Farmer's employment (Z_{10})	ρ_{10}	-	- 0.0003	0.0156	-0.9
Education of farm attendant (Z_{11})	ρ_{11}	-	+ 0.0001	0.0043	0.56
Age of attendant (Z_{12})	ρ_{12}	-	-0.0002	0.0019	-0.76
Sex of farmer (Z_{13})	ρ_{13}	-	-0.0702	0.3066	-0.61
Age of farmer (Z_{14})	ρ_{14}	-	+ 0.0001	0.0052	0.19
Adjusted R^2				78.1%	
Durbin Watson statistics				1.72	
Condition index number				12.78	
Degrees of freedom				73	

*** = α = 0.1; ** = α = 0.05; and * = α = 0.001 reflect levels of significance.

tend to have lower TE, may be explained by the fact that often such farmers have alternative sources of income such that they do not pay much attention to the performance of the poultry farm. The positive sign on the parameter for location implies that farms that are further away from the city center tend to have a lower technical efficiency.

There was a negative sign on the famer's; marital status (- 0.9813), level of education (- 0.5117), use of credit (- 0.3308) and family size (- 0.0014). All these parameter estimates were significantly different from zero at the level of significance of 99, 95 and 90%, respectively. The coefficients on farmers' sex (- 0.0702), farmers' alternative employment (- 0.0003), age of farm attendants (- 0.0002) and use of lighting in the chicken houses (- 0.3243) were also negative but not significantly different from zero. The negative sign on all these variables means an increase in the variables also increased TE. Thus, married farmers tended to be more technically efficient, probably reflecting more availability of labor, which is consistent with larger families having more labor at their disposal, thus contributing to higher TE. Similarly, farmers with more education are more likely to use farm resources more efficiently especially in relation to feed mix and use medicine, and they are more likely to use credit for acquiring the inputs. Such farmers also tend to have alternative employment, and the salaries can be used to finance poultry enterprises. The negative sign on lighting of the chicken house reflects the relationship between lighting and feeding. As birds feed for longer periods in a day, they tend to be more productive (Ryan, 2004).

The results also imply that female farmers tend to have higher TE than their male counterparts, which is consistent with the finding that the mean TE of female farmers was 68% compared to 60.5 for male farmers (Table 7a). Younger farm attendants also contribute to higher TE of the farm, probably because they tend to adhere more to instructions they are given on feeding and general hygiene of the poultry houses. This confirms the finding reported earlier that farm attendants who have worked for the farm longer tended to reduce TE which as previously argued may reflect their tendency to put less than their best effort, banking on the trust upon them, hence, less likely to be supervised as closely as newer attendants who should be expected to be relatively younger. All these findings show that there is much room for improving the performance of egg production enterprises in Kibaha and Temeke district by focusing on improving the technical efficiency and hence the net returns farmers receive for their capital and labour investment. These findings could also be extrapolated to other parts of Tanzania where similar poultry productions systems are found.

Conclusions

The study established that there are differences in the performance of farmers in the study area as measured by the technical efficiency of their egg production enterprises. The stock size has the most significant effect in the variation of the value of production, followed by the amount of feed and other operating cost. Variation in the transport cost and the cost of drugs do not contribute as much to variation in the dependent variable. Majority of the farms are small (85%) having flock sizes in the range of 100 to 1,000 birds and a mode of 300. The results however, revealed that bigger flock sizes are associated with higher TE implying the need to expand flock size. The overall mean technical efficiency is estimated at 64.8% implying that, there is a 35.2% scope for increasing egg production by using the present technology

Performance differences between farmers in Kibaha and Temeke districts have been attributed to education and levels of investment. Farmers in Kibaha district were more educated on average; they also operate larger farms (flock sizes) which provide for economies of scale. The high cost of production has been shown to reduce the competitiveness of poultry farmers. One of the most important avenues for reducing production cost is to increase output, which would lower average cost of production and hence improve technical efficiency. Farm owners should also set up management systems that provide for better supervision of their farm attendants. Farm owners should not relax and bank on their long term relationship with employees. Poor management reduces yield and hence increases the average cost of producing each egg. Credit, which had a positive and significant effect on technical efficiency, is necessary to encourage technical innovation and timely availability of necessary inputs. The government should influence borrowing rates on credit in order to spur more and faster transformation of the poultry industry in Tanzania thereby contribution to realizing national development goals to overcome food insecurity, improve nutrition and overcome poverty. These findings can be used by agricultural extension agents to develop training programmes for poultry farmers that aim at improving at farm performance by raising their technical efficiency so that majority of farmers operate close to the production frontier.

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