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Application of Stochastic Frontier Model for Poultry Broiler Production: Evidence from Dhaka and Kishoreganj Districts, Bangladesh

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This paper analyses the technical efficiency of poultry broiler production in Bangladesh from a sample of 100 poultry farmers selected from Savar and Dhamrai upazilla under Dhaka district and Bajitpur and Kuliarchar upazilla under Kishoreganj district. Stochastic parametric technique was used to analyse the technical efficiency of poultry farmers. Results show that among different input factors, doc size and feed input play crucial role in broiler output. Estimated mean technical efficiencies were 43%, 52% and 68% for small, medium and large farms respectively. The difference in the level of technical efficiency postulates the existence of further opportunities for broiler farmers to escalate their meat productivity and income through enhancements in their technical efficiency. Different observed socioeconomic variables related to farming experience, age, education, family size, training, credit, extension contact and regular medication are found to be negative and significantly related to technical inefficiency.

Keywords: Meat Production, Technical Efficiency, Frontier Analysis, Poultry Farmers
JEL Classification:Q12, C13, C14

I. INTRODUCTION

As per FAO (2015), availability, accessibility and sufficient quantity and quality of food are required for food security and promoting human development. In this context, ensuring adequate availability and access to protein, especially animal protein, remains a huge challenge. Isika, Agiang and Okon (2006) suggest poultry production as an excellent source of animal protein due to its shorter life cycle, high rate of return and its proficiency in conversion to high class animal protein.

The poultry industry is a cheap source of good quality, nutritious animal protein (Shamsuddoha 2010). Poultry is the leading livestock group which

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generally includes chicken, duck and turkey (FAO 2009). Poultry products (eggs and meat) constitute 30 per cent of all animal protein consumed worldwide (Permin, Pedersen and Riise 2005), that is, poultry meat accounts for 30 per cent of total global meat consumption, ranking second place after pork (FAO Corporate Document Repository 2007).

The poultry sector has good potential in promoting agricultural growth. Seventy-three per cent of people in rural areas are engaged in poultry production (Reneta 2005). By 2020, per capita poultry meat consumption in the country is expected to reach 8.42kg from 4kg, compared to 5.5kg in Pakistan and over 50kg in the United States. In the 1990s, total investment in the poultry sector was only Tk 1,500 crore, which now stands at more than Tk 15,000 crore.

Poultry industry has the potential to support Bangladesh attain the UN Sustainable Development Goals (SDGs) by reducing malnutrition and promoting better health of the people. Among 17 SDGs, ending hunger, achieving food security and improving nutritional status are the ones that the poultry industry can impact upon.

Annual growth rate of poultry is 15-18 per cent, and it contributes 2.4 per cent to GDP. About 38 per cent of animal protein originates from poultry meat and eggs (Layer Rearing Manual, 2010, BLRI). Table I shows the contribution of agriculture sub-sectors to GDP at constant (2005/06) prices. Although the share of the agriculture sector in GDP is declining, the livestock subsector has grown at over 3.3 per cent per annum.

TABLE I

CONTRIBUTION OF AGRICULTURE TO GDP BY SUB-SECTOR (%)

Sub-sector	Contribution of Agriculture to GDP in Percentage (GDP at Constant Price—Base Year 2005/06)								
	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16*
Crop	10.9	10.6	10.8	10.5	10.0	9.5	9.3	8.9	8.3
Livestock	2.2	2.1	2.1	1.9	1.9	1.8	1.8	1.7	1.7
Forestry	1.8	1.8	1.8	1.8	1.8	1.8	1.7	1.7	1.7
Total	14.9	14.6	14.7	14.3	13.7	13.1	12.8	12.3	11.7
Fisheries	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.7	3.6

Source: *Bangladesh Economic Review*, 2016, Table: 2.4; p. 21.

TABLE II

CONTRIBUTION OF LIVESTOCK IN GDP

Indicators	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-2016	2016-2017p
GDP (Base:2005-06)**	2.1	1.9	1.9	1.8	1.8	1.7	1.7	1.6
Growth rate of GDP	2.5	2.6	2.7	2.7	2.8	3.1	3.2	3.3

Note:**GDP calculated at constant prices (Source: BBS); p denotes provisional.
Source: DLS, 2017.

Table III shows the rapid growth of the livestock and poultry population of the country for the period 2000-2017.

TABLE III

NUMBER OF LIVESTOCK AND POULTRY IN BANGLADESH

(NUMBER IN MILLIONS)

Year	Cattle	Buffalo	Goat	Sheep	Total (Livestock)	Chicken	Duck	Total (Poultry)
2000-01	22.39	0.92	16.27	2.11	41.69	142.68	33.83	176.51
2001-02	22.46	0.97	16.96	2.2	42.59	152.24	34.67	186.91
2002-03	22.58	1.01	17.69	2.29	43.57	162.44	35.54	197.98
2003-04	22.6	1.06	18.41	2.38	44.45	172.63	36.4	209.03
2004-05	22.67	1.11	19.16	2.47	45.41	183.45	37.28	220.73
2005-06	22.8	1.16	19.94	2.57	46.47	194.82	38.17	232.99
2006-07	22.87	1.21	20.75	2.68	47.51	206.89	39.08	245.97
2007-08	22.9	1.26	21.56	2.78	48.5	212.47	39.84	252.31
2008-09	22.97	1.31	22.4	2.87	49.55	221.39	41.23	262.62
2009-10	23.05	1.35	23.27	2.97	50.64	228.04	42.67	270.71
2010-11	23.12	1.39	24.14	3.02	51.67	234.68	44.12	278.8
2011-12	23.19	1.44	25.11	3.82	53.56	242.86	45.7	288.56
2012-13	23.24	1.45	25.11	3.12	53.2	249.6	47.23	296.23
2013-14	23.48	1.45	25.43	3.20	53.59	255.3	48.86	304.1
2014-15	23.63	1.46	25.60	3.27	53.97	261.7	50.52	312.2
2015-16*	23.73	1.46	25.71	3.31	54.27	266.07	51.62	317.7
2016-17	23.93	1.47	25.93	3.41	64.74	275.18	54.01	329.2

Note:* indicates up to February, 2016.**Source**: Department of Livestock, Ministry of Fisheries and Livestock.
Ref: Year 2001-2010: Bangladesh Economic Review 2012, Chp-7: Agriculture, Table: 5.10, page-50
Year 2011-2013: Bangladesh Economic Review 2013, Chp-7: Agriculture, Table: 6.11, page-69
Year 2014-2016: Bangladesh Economic Review 2016, Chp-7: Agriculture, Table: 7.8, page-93
Year 2016-2017: Bangladesh Economic Review 2017, Chp-7: Agriculture, Table: 7.8, page-110

The contribution of livestock and poultry in the national economy of Bangladesh is presented in Table IV.

TABLE IV

CONTRIBUTION OF LIVESTOCK AND POULTRY IN THE NATIONAL ECONOMY OF BANGLADESH

Particulars	Contribution
Contribution of livestock in gross domestic product (GDP), (2016-17)p	1.6%
GDP growth rate of livestock (2016-17) p	3.3 %
GDP volume (current price) in crores (Taka), (2016-17) p	35,576
Share of livestock in agricultural GDP (2016-17) p	14.3%
Employment (directly)	20%
Employment (indirectly)	50%
Cultivation of land by livestock	50%
Fuel supply from livestock and poultry	25%

Source: DLS, 2017.

Although poultry plays an important role in the national economy, there has been no study that investigates the status of poultry sector from the perspective of efficiency. In order to establish a sustainable poultry-friendly strategy for the country, it is essential to assess the sector in terms of efficiency. Given the fact that Bangladesh is faced with different challenges as far as the livestock subsector is concerned, it becomes crucial to quantitatively measure the existing level and determinants of efficiency and policy options available for achieving gains in efficiency.

The measurement of farm efficiency is a central area of research both in the developed and developing world (Binuomote, Ajetomobi and Ajao 2008). Efficiency is an essential factor of productivity growth, particularly in developing countries faced with resource scarcity. Moreover, efficiency as an economic concept is used in assessing producers' performance to make sure that products are produced in the best and most profitable way (Park *et al*. 2010). Technical inefficiency (TE) is defined as the amount by which the level of production for the farm is less than the frontier output (Kibaara 2005). The analysis of efficiency is generally associated with the possibility of farms producing a certain optimal stage of output from a certain level of resources or given level of output, at least cost (Battese and Coelli 1995, Parikh and Shah 1995).TE denotes the ability of firms to employ the "best practice" in an industry so that not more than the required amount of a given set of inputs is used in producing the "best" level of output (Ajibefun, Battese and Kada 2002 and Ohajianya, Obasi and Orebiyi

2006). A measure of producer performance is often worthwhile for policy purposes and the idea of economic efficiency provides a theoretical basis for such a measure (Alrwis and Francis 2003).

The specific objectives of this paper are to estimate the determinants of poultry broiler farm output by estimating the elasticity of production of the inputs; and technical efficiency of table poultry broiler farms in Savar and Dhamrai upazilla under Dhaka district and Bajitpur and Kuliarchar upazilla under Kishoreganj district.

A good number of studies have been undertaken on different aspects of poultry and poultry farms in Bangladesh. The studies include production performance of poultry and demand for poultry (Ukil and Paul 1994, Islam 2001, Khan *et al*. 2006, Rahman *et al.* 2009, Shah, Sharmin and Haider 2011), measuring relative costs, returns and economic analyses (Miah 1990, Ahmed, Ali and Begum 1995, Bhuiyan 2003, Alam 2004, Islam *et al*. 2016), benefit and profitability analysis of contract farming (Karim 2000, Bairagi 2004, Jabbar *et al.* 2007), effectiveness of trained farmers (Ershad *et al.* 2004), marketing and value chain analysis (Rahman 2004, USAID-ATDP 2005), role of NGOs in poultry (Ahmed 2001, Shamsuddoha 2009), role of poultry in biogas and electricity generation (Zaman 2007, Sajib and Hoque 2015, Alam 2017), environmental impact of the poultry sector in Bangladesh (Akter *et al.* 2004), etc.

However, these studies were mostly descriptive in nature and suffered from lack of rigorous economic analysis. These mainly focused on the production, marketing and distribution aspect of poultry employing simple cost-benefit analysis. There have been some studies that have examined the efficiency of agricultural production in Bangladesh based on stochastic frontier (SFA) and data envelopment analysis (DEA) (Wadud and White 2000, Kamruzzaman, Manos and Begum 2006, Haider, Ahmed and Mallick 2011, Uddin, Hossain and Hasnain 2017) focusing on major food crops like rice, wheat, fish, maize, etc. No studies have dealt with the poultry industry, using these approaches.

The present study differs from previous studies in Bangladesh by introducing the concept of efficiency considering variables that relate to both individual aspects and aspects of the decision-making process of the farmer in the form of well-known production function and stochastic frontier analysis (SFA).

Two approaches are mainly used to estimate technical efficiency i.e. parametric and non-parametric. The parametric approach includes stochastic frontier analysis (SFA) while non-parametric approach includes the data envelopment analysis (DEA) method. DEA is known to be sensitive to outliers (Hasnain, Hossain and Islam 2015). The main disadvantage of employing this mathematical technique is that it does not take into account other sources of statistical noise besides the inefficiency (Coelli and Battese 2005). For this reason, we also use the parametric approach (SFA). This approach takes into account the stochastic noise of the data where the data envelopment analysis assumes there is no stochastic noise (Abedullah and Mushtaq 2007). The rest of the paper is structured as follows. Section II describes data and methodology. Section III highlights and analyses results while section IV concludes with some suggestions.

II. DATA AND METHODOLOGY

2.1 Materials and Methods

The study was carried out at Savar and Dhamrai upazilla under Dhaka district and Bajitpur and Kuliarchar upazilla under Kishoreganj district. Data were collected from 100 poultry farmers selected randomly from these two areas using a structured questionnaire. Data analysis was done using Stochastic Production Frontier Model. Stata 14 was applied to run the frontier model.

2.2 Source of Data

Both primary and secondary data were used. Primary data were collected from farmers involved in the production of poultry broiler meat. In addition, the study also used information from different issues of *Bangladesh Statistical Year Book* published by Bangladesh Bureau of Statistics (BBS), *Bangladesh Economic Review* published by Ministry of Finance and *Farm Poultry and Livestock Survey 2007-08* conducted by BBS. At first 115 poultry farmers were selected and after necessary scrutiny, 100 poultry farmers were retained for the study. Finally, the farms were categorised in terms of the number of birds reared in the farm, followed by BBS.

TABLE V

CATEGORISATION OF FARMS

No. of Birds	Categories of Farms
Up to1,000 birds	Small
1,001-5,000 birds	Medium
Above 5,000	Large

Sources: *Farm Poultry and Livestock Survey 2007-08*, BBS.

2.3 Analytical Framework

A production function is the functional relationship describing the maximum output that can be produced from a specific set of inputs, given the existing technology available to the firms involved.

A Stochastic Production Function is defined by

$$Yi = F\,(Xi, B)\exp\,(Vi - Ui),\ i = 1, 2 - n \tag{1}$$

where Yi is output of the ith farm, Xi is the vector of input quantities used by the ith farm, B is a vector of unknown parameters to be estimated, *f(.)* represents an appropriate function (e.g., Cobb – Douglas, translog, etc). The term Vi is a symmetric error, which accounts for random variations in output due to factors beyond the control of the farmer e.g., weather, disease outbreaks, measurement errors, etc., while the term Ui is a non-negative random variable representing inefficiency in production relative to the stochastic frontier. The random error Vi is expected to be independently and identically dispersed. The Stochastic Frontier model was first applied by Aigner,Lovell and Schmidt (1977) and Meeusen and Broeck (1977) independently.

According to Battese and Coelli (1995), technical inefficiency effect is defined by

$$u_i = \sum_{i=1}^{N} \delta_i Z_i + W_i$$

where Z_i is a vector of explanatory variables associated with the technical inefficiency effects. $\delta_i$is a vector of unknown parameter to be estimated and W_i is unobservable random variables, which are assumed to be identically distributed, obtained by truncation of the normal distribution with mean zero and unknown variance σ^2, such that u_i is non-negative.

i. The Empirical Model

For this study, the production technology of poultry meat producers was assumed to be specified by the Cobb – Douglas frontier production function defined as follows:

$$Y = aX_1^{\beta_1} X_2^{\beta_2} X_3^{\beta_3} X_4^{\beta_4} X_5^{\beta_5} X_6^{\beta_6} X_7^{\beta_7} e^{V_1 - U_1} \tag{2}$$

$$Y = f(X_a\,;\,B_i)e^E$$

where

Y= Quantity of broiler produced

X_a = A vector of input and other explanatory variable quantities

Bi= A vector of unknown parameter to be estimated

e=Error term

E=Stochastic disturbance term consisting of two independent elements which are Ui and Vi , where by E = Ui + Vi

Ui = One-sided efficiency component with a half normal distribution

Vi =The non-negative unobservable random variable

The random error E represents random variations in the economic environment facing the production units, reflecting chance such as weather, disease outbreak and variable input quality, measurement errors, and omitted variables from the functional form (Aigner, Lovell and Schmidt 1977).

Cobb-Douglas production function model can be estimated, using OLS (ordinary least square) method, in a linear form. The estimated equation is as follows:

$$\ln Y_i = \ln_a + \beta_1 \ln X_{1\,i} + \beta_2 \ln X_{2\,i} + \beta_3 \ln X_{3\,i} + \beta_4 \ln X_{4\,i} + \beta_5 \ln X_{5\,i} + (v_i - u_i) \qquad (3)$$

$$\ln Y_i = \beta_0 + \beta_1 \ln X_{1\,i} + \beta_2 \ln X_{2\,i} + \beta_3 \ln X_{3\,i} + \beta_4 \ln X_{4\,i} + \beta_5 \ln X_{5\,i} + (v_i - u_i) \qquad (4)$$

where,

ln = the natural logarithm to base e

Y_i = Output of the poultry farmer per batch (total meat produced per batch in kg)

X_1= Number of days worked in a year

X_2= Size of Doc (number of birds per batch)

X_3= Cost of feed per batch (in taka)

X_4= Value of capital (in taka)

X_5= Farm Area measured in decimal

v_i= random error assumed to be independent of u_i, identical and normally distributed with zero mean and constant variance $N(0,\partial^2)$

Ui = Technical efficiency effects which are the result of behaviour factors that could be controlled by an efficient management.

In equation 4, $\beta_0$is the intercept; *Ui* denotes the specific technical efficiency factor for farm *i*; and *vi* represents a random variable for farm *i*. The β coefficients are unknown parameters to be estimated, by the method of maximum likelihood, using the econometric package Stata version 14.

ii. Measuring Inefficiency Determinants

In addition to the general production model mentioned above, the efficiency model was also defined to estimate the impact of socioeconomic variables on the technical efficiencies of the broiler farmers. The model was defined by

$$Ui = Z_0 + \delta_1 \ln Z_1 + \delta_2 \ln Z_2 + \delta_3 \ln Z_3 + \delta_4 \ln Z_4 + \delta_5 \ln Z_5 + \delta_6 \ln Z_6 + \delta_7 \ln Z_7 + \delta_8 \ln Z_8 + \delta_9 \ln Z_9 \, \delta_{10} Z_{10} + \delta_{11} Z_{11} + \delta_{12} Z_{12} + \delta_{13} \ln Z_{13} + \delta_{14} \ln Z_{14} + W_i \quad (5)$$

Where

Ui = Technical (or economic) efficiency of the ith farmer already mentioned above

Z_1 = Years of farming experience in poultry production of the ith farmer

Z_2 = Age of the farmers (in years)

Z_3 = Level of formal education (years of schooling)

Z_4 = Household size (family members in number)

Z_5 = Training on poultry (if Yes=1; No=0)

Z_6 = Access to credit facility (if Yes=1; No=0)

Z_7 = Meetings with extension agents/respective government. agencies per poultry production season (Yes=1;No=0)

Z_8 = Location of farms (Urban=1; Rural=0)

Z_9 =Types of poultry occupation

(1 = Poultry as main occupation and no other job

0 = Poultry as part time occupation and do other job also)

Z_{10} =Marital status (Married=1; Unmarried = 0)

Z_{11} =Membership of farmers association/cooperative society (Yes=1; No=0)

Z_{12} =Ownership of the farm (where Sole proprietor=0, Partnership=1

Z_{13} =Gender (if Female=1; Male=0)

Z_{14} =Regular medication/vaccination facilities (Yes=1; No=0)

Z_0 = Constant

W_i = Unobservable random variables

To determine the contributing factors to the observed technical efficiency, the above model was formulated and the δ coefficients are unknown parameters to be estimated.

III. RESULTS AND DISCUSSION

3.1 Descriptive Statistics of Broiler Farmers

Table I shows the summary descriptive statistics of the broiler farms. The table shows that in the study area the mean flock size was 2,567 birds. The average year of experience of farmers was 5.4 years and the mean age of farmers was 40. The poultry farmer's average family size was 5.

TABLE VI

BROILER DESCRIPTIVE STATISTICS

Variable	Obs	Mean	Std. Dev.	Min	Max
Flock size	100	2,567.1	2,559.238	100	1000
Experience	100	5.423	3.260286	1	15
Age	100	40.13	7.34662	18	54
Family members	100	5.03	1.714201	0	9

***Source**:* Field survey, 2015.

3.2 Estimated Stochastic Frontier Production Function for Broiler Farms

The estimates for parameters of the Cobb-Douglas production function are shown in Table VII, VIII and IX. These parameters represent percentage change in the dependent variable as a result of percentage change in the independent variables, and thus show the relative position of these variables to meat productivity. Tables VII through IX also show elasticity of production and returns to scale.

3.2.1 Frontier Function for Small Broiler Farms

Labour input ($\ln X_1$) measured as person-days, affected poultry production positively and was observed significant at 1% level in the study area, indicating that labour activities are necessary to increase poultry output. Poultry production is labour intensive and the more attention farmers paid to the birds, the more was the poultry output. Thus the 0.10 elasticity of labour (Table VI) suggests that a 1% increase in labour use would result in an increase of 0.10 per cent in the farm output, given that other inputs are constant. DOC size ($\ln X_2$) was significant at 1% level and positive in sign, as expected, which means that farmers who stock higher number of birds were producing more than those with smaller farm size. The coefficient was 0.23 ($\ln X_2$), implying that a 1 per cent increase in the number of day old chicks (DoC) will result in a 0.23 per cent in the number of broilers produced per cycle, other things remaining constant. The estimated coefficient of feed input ($\ln X_3$) was positive and significant at 1% level. Feed appeared to be the most vital production factor with the elasticity of 0.25 and was significant at 1% level. This is in agreement with the concept of weight gain in broiler production. Broilers that are well fed gain weight sooner and reach marketable weights earlier and are sold at higher unit prices. Capital input ($\ln X_4$) variable was also significant and positive in sign. As more capital is invested in the poultry business, there is increased poultry production by farmers. Thus the 0.12 elasticity of feed suggests that a 1% increase in feed inputs would result in an increase of 0.12 per cent in the farm output. Finally, the estimated coefficient for *farm area* ($\ln X_5$) measured in decimal was positive and significant at 5% level. Output of poultry primarily depends on farm size. Therefore, the 0.07 elasticity of *farm size* implies that a 1% increase in farm size, ceteris paribus, would lead to an increase of 0.07 per cent in the output of poultry broiler farmers holding *ceteris paribus* and vice versa.

TABLE VII

COBB-DOUGLAS PRODUCTION FUNCTION FOR SMALL BROILER FARMS

Number of obs	=42			
F(5, 36)	= 26.5	R-squared	= 0.785	
Prob> F	= 0.000	Adj R-squared	= 0.745	
$\ln Y_{meat}$	Coef.	Std. Err.	t	P>t
$\ln X_1$	0.101	0.028	3.612	0.000
$\ln X_2$	0.232	0.096	2.414	0.020
$\ln X_3$	0.250	0.066	3.780	0.000
$\ln X_4$	0.123	0.025	4.771	2.343E-05
$\ln X_5$	0.076	0.038	1.952	0.048
_cons	-1.005	0.430	-2.337	0.001
RTS	0.784			

Source: Author's calculation from the field data.

Note: $\ln X_1$ = Labour input, $\ln X_2$ = DOC size, $\ln X_3$ = Feed input, $\ln X_4$ =Capital input and $\ln X_5$ = Area of farm.

3.2.2 Frontier Function for Medium Broiler Farms

All the variables in this case had positive coefficients, implying that any increase in such variables would lead to an increase in output in the meat production enterprise, as can be seen from Table VIII. Feed input plays a significant role in this case also (the value of elasticity was 0.26).

TABLE VIII

COBB-DOUGLAS PRODUCTION FUNCTION FOR MEDIUM BROILER FARMS

Number of obs	=32			
F(5, 36)	= 17.5	R-squared	= 0.771	
Prob> F	= 0.000	Adj R-squared	= 0.726	
$\ln Y_{meat}$	Coef.	Std. Err.	t	P>t
$\ln X_1$	0.135	0.038	3.491	0.001
$\ln X_2$	0.240	0.090	2.668	0.012
$\ln X_3$	0.269	0.050	5.345	0.000
$\ln X_4$	0.090	0.024	3.669	0.001
$\ln X_5$	0.059	0.028	2.046	0.04
_cons	1.100	0.305	3.598	0
RTS	0.794			

Source: Author's calculation from the field data.

Note: $\ln X_1$ = Labour input, $\ln X_2$ = DOC size, $\ln X_3$ = Feed input, $\ln X_4$ =Capital input and $\ln X_5$ = Area of farm.

3.2.3 Frontier Function for Large Broiler Farms

Table IX shows the output elasticity of large broiler farms. In this case, results were similar as well. All the variables affected the output positively and all were significant at 5% and 1% levels.

TABLE IX

COBB-DOUGLAS PRODUCTION FUNCTION FOR LARGE BROILER FARMS

Number of obs	=26			
F(5, 36)	= 12.26	R-squared	= 0.754	
Prob> F	= 0.000	Adj R-squared	= 0.692	
$\ln Y_{meat}$	Coef.	Std. Err.	t	P>t
$\ln X_1$	0.107	0.048	2.191	0.038
$\ln X_2$	0.254	0.101	2.520	0.019
$\ln X_3$	0.299	0.090	3.327	0.002
$\ln X_4$	0.119	0.029	4.090	0.000
$\ln X_5$	0.067	0.028	2.323	0.028
_cons	0.992	0.171	5.772	0.000
RTS	0.847			

Source: Author's calculation from the field data.

Note: $\ln X_1$ = Labour input, $\ln X_2$ = DOC size, $\ln X_3$ = Feed input, $\ln X_4$ =Capital input and $\ln X_5$ = Area of farm.

3.3 Determinants of Technical Efficiency

3.3.1 Inefficiency Determinants for Small Broiler Farms

The inefficiency model presented in Table X gave some insights on factors affecting technical efficiency.

There were negative coefficients before most of the variables. All the parameter estimates were significantly different from zero. The coefficients on gender and ownership of farm were also negative but not significantly different from zero. The negative sign of variables means an increase in the variables decreases technical deficiency, or increases technical efficiency (TE).The signs and significance of the inefficiency model of the stochastic frontier production function has significant implications for the technical efficiency of poultry broiler farms.

The estimated coefficient of farming experience (Z_1) was negative and statistically significant at 0.01 level, which indicates that farmers with more years of farming experience in poultry production were relatively more efficient. The more the farmers stay in the poultry farming business, the more they get acquainted with the risk elements and learn ways of mitigating possible losses. Therefore, 0.36 elasticity of experience suggested that a 1% increase in farming experience would result in an increase of 0.36 per cent in the farm output.

The estimated coefficient for age (Z_2) of the farmers was estimated to be negative, as expected, and significant at 0.01 significance level. It is believed that more experienced farmers utilise scarce resources more efficiently.

The estimated coefficient of education variable (Z_3) was negative and significant at 0.01 significance level. The implication is that poultry farmers with more years of schooling tend to be more efficient in poultry production. Farmers with higher education respond readily to the use of improved technologies, thus producing closer to the frontier. Therefore, 0.40 elasticity of capital suggested that a 1% increase in capital inputs would result in an increase of 0.40 per cent in farm output.

The estimated coefficient of household size variable (Z_4) was negative and statistically significant at 0.01 significance level, suggesting that farmers who had more family members in their households tended to be more efficient in poultry production. More adults in family members mean more labour force and thus savings in hired labour costs. Therefore, 0.25 elasticity of capital suggested that a 1% increase in capital inputs would result in an increase of 0.25 per cent in farm output.

The estimated coefficient of training (Z_5) was negative and statistically significant at 0.01significance level, suggesting that farmers who received training tend to be more efficient in poultry production. Therefore, 0.39 elasticity of training variable suggests that a 1% increase in training would result in an increase of 0.39 per cent in farm output.

The estimated coefficient for access to credit (Z_6) was negative and significant at 0.05 level. This implies that farmers, who have greater access to credit tend to be more efficient in poultry production. Availability of credit helps increase farm size and provides adequate production and maintenance inputs. Therefore, elasticity of capital of 0.18 suggests that a 1% increase in capital inputs would result in an increase of 0.18 per cent in farm output.

The estimated coefficient for extension visit (Z_7) was negative and significant at 0.01 level, implying that farmers who had more extension visits tended to be more efficient in poultry production. Extension visit is necessary in poultry farming because it affords the farmers the opportunity to learn improved technologies and new techniques of farming. Therefore, elasticity of capital of 0.07 suggests that a 1% increase in capital inputs would result in an increase of 0.07 per cent in farm output.

The estimated coefficient for location (Z_8) was negative and significant at 0.05 level. The negative sign on the parameter for location implies that farms that were further away from the city or urban area or located in rural areas tend to have lower technical efficiency.

The estimated coefficient for poultry occupation (Z_9) was negative and not significant at 0.01 or even at 0.05 level. Perhaps the type of poultry occupation is not a matter of great concern. Poultry is an activity that can be conducted side by side other agricultural or even non-agricultural activities. Poultry production does not require full time effort. This is an important reason for the rising popularity of poultry business among people.

The estimated coefficient of married variable (Z_{10}) was negative and significant at 0.05 probability level. Thus married farmers tended to be technically more efficient, probably reflecting greater availability of labour. The estimated coefficient for membership of association (Z_{11}) was negative but insignificant. Though the negative sign on the parameter indicated that membership of farmers' association might lower technical inefficiency, the result was not significant. The estimated coefficient for ownership of the farm (Z_{12}) was negative but insignificant. Besides, the value of the estimated coefficient was negligible. That is, type of ownership of farm does not affect poultry efficiency. The estimated coefficient for gender (Z_{13}) was negative but insignificant. The negative sign implies female farmers tend to have higher technical efficiency than their male counterparts.

The estimated coefficient for regular medication input (Z_{14}) was positive and statistically significant at 0.01 level. Poultry production involves high levels of risk, because the birds are susceptible to various diseases and pest attack. To lessen these, drugs have to be provided. Also, certain drugs are needed in their ration to improve their growth and performance. So the appropriate amount of drugs used determines the level of success and profitability in poultry business. Therefore, 0.41 elasticity of capital suggests that a 1% increase in capital inputs would result in an increase of 0.41 per cent in farm output.

Diagnostic statistics: The total variance value of sigma square was 0.54 which was highly significant, indicating a good fit and the correctness of the specified distribution assumption of the composite error term. Furthermore, a high value of the natural log for the likelihood functions (-13.77), which is always negative, means the observed results were more likely to occur, again implying a high predictive ability of the model. The value of Gamma (0.608) measures the relationship between random variation in the production of meat and inefficiency in the use of inputs. The computed value of 0.608 indicates that 61% of the random variation in broiler production was explained by inefficiency in resource utilisation, implying that the OLS estimates will not be adequate to explain the inefficiencies of poultry broiler farming. Hence, the specification of a stochastic frontier production function was justified. The mean TE was 0.43 (43%), suggesting that the farmers were not fully efficient as the observed output was 57% less than the maximum output.

TABLE X

ESTIMATED DETERMINANTS OF TECHNICAL INEFFICIENCY FOR SMALL BROILER FARMS

Variable	Parameter	Coefficient	Std. Err.	Z	P[|Z|>z]
Farming experience in poultry production (in years)	Z1	-0.487	0.110	-4.428	0.000
Age of the farmers	Z2	-0.111	0.056	-1.981	0.047
Level of education	Z3	-0.312	0.139	-2.241	0.025
Family size	Z4	-0.520	0.125	-4.151	3.30E-05
Training on poultry	Z5	-0.470	0.188	-2.502	0.012
Access to credit facility	Z6	-0.220	0.112	-1.969	0.042
Meeting with extension agent/govt. agency	Z7	-0.110	0.046	-2.409	0.016
Location of farm	Z8	-0.059	0.028	-2.098	0.036
Types of poultry occupation	Z9	-0.007	0.008	-0.834	0.423
Marital status	Z10	-0.121	0.059	-2.027	0.045
Membership of farmers association/cooperative society	Z11	-0.016	0.019	-0.834	0.423
Ownership of the farm	Z12	0.0082	0.101	0.081	0.936
Gender	Z13	-0.119	0.050	-2.39	0.016
Regular medication/vaccination facilities	Z14	-0.518	0.095	-5.457	0.000
Constant	Z0	2.765	0.156	17.700	0.000
Diagnostic Statistics					
sigma2		0.543	0.092	5.858	
gamma		0.608	0.153	3.960	
Log Likelihood		-13.771	2.228	-6.180	
Mean TE		0.43			
No. of observations		42			

Source: Author's calculation.

3.3.2 Inefficiency Determinants for Medium Broiler Farms

In this case, except the variable ownership of the farm, Z_{12}, the estimated coefficient of farming experience (Z_1), age (Z_2), education (Z_3), farm location (Z_8), poultry occupation (Z_9), marital status (Z_{10}), membership of association (Z_{11}), gender (Z_{13}) and regular medication input (Z_{14}) all were negative and significant at 0.05 level. Household size (Z_4), training (Z_5), access to credit (Z_6) and extension visit (Z_7) were significant at 1 per cent level.

Diagnostic statistics: The value of sigma square was 0.61, which was significant, indicating a good fit and the correctness of the specified distribution assumption of the composite error term. The computed value of Gamma was 0.578, suggesting that 58% of the random variation in production was explained by inefficiency in resource utilisation. The mean TE was 0.52 (52%), implying that the farmers were not fully efficient as the observed output was 48% less than the maximum output.

TABLE XI

ESTIMATED DETERMINANTS OF TECHNICAL INEFFICIENCY FOR MEDIUM BROILER FARMS

Variable	Parameter	Coefficient	Std. Err.	Z	P[|Z|>z]
Farming experience in poultry production (in years)	Z1	-0.299	0.150	-1.989	0.047
Age of the farmers	Z2	-0.129	0.058	-2.193	0.035
Level of education	Z3	-0.389	0.178	-2.175	0.030
Family size	Z4	-0.470	0.141	-3.330	0.000
Training on poultry	Z5	-0.371	0.123	-3.017	0.002
Access to credit facility	Z6	-0.276	0.095	-2.909	0.003
Meeting with extension agent/govt. agency	Z7	-0.091	0.032	-2.860	0.004
Location of farm	Z8	-0.086	0.039	-2.163	0.030
Types of poultry occupation	Z9	-0.010	0.005	-1.724	0.085
Marital status	Z10	-0.047	0.022	-2.090	0.045
Membership of farmers association/cooperative society	Z11	-0.030	0.015	-1.967	0.049
Ownership of the farm	Z12	0.002	0.004	0.535	0.592
Gender	Z13	-0.063	0.031	-1.987	0.047
Regular medication/vaccination facilities	Z14	-0.417	0.192	-2.172	0.030
Constant	Z0	0.943	0.156	6.036	0.000
Diagnostic Statistics					
sigma2		0.61	0.059	10.309	
gamma		0.578	0.130	4.440	
Log Likelihood		-17.449	1.998	-8.732	
Mean TE		0.52			
No. of observations		32			

Source: Author's calculation.

3.3.3 Inefficiency Determinants for Large Broiler Farms

In the case of large farms, the estimated coefficient of all variables was negative and significant at 0.05 and 0.01 levels.

Diagnostic statistics: The value of sigma square was 0.67, which was significant. This result indicates a good fit and the correctness of the specified distribution assumption of the composite error term. The computed value of Gamma was 0.78, indicating that 78 per cent of the random variation in production was explained by inefficiency in resource utilisation. The mean TE was 0.68 (68%), implying that the farmers were not fully efficient as the observed output was 32% less than the maximum output.

TABLE XII

ESTIMATED DETERMINANTS OF TECHNICAL INEFFICIENCY FOR LARGE BROILER FARMS

Variable	Parameter	Coefficient	Std. Err.	Z	P[|Z|>z]
Farming experience in poultry production (in years)	Z1	-0.300	0.100	-3.003	0.000
Age of the farmers	Z2	-0.182	0.085	-2.141	0.032
Level of education	Z3	-0.422	0.140	-3.014	0.002
Family size	Z4	-0.327	0.097	-3.344	0.000
Training on poultry	Z5	-0.398	0.121	-3.293	0.001
Access to credit facility	Z6	-0.284	0.130	-2.188	0.029
Meeting with extension agent/govt. agency	Z7	-0.120	0.058	-2.055	0.045
Location of farm	Z8	-0.077	0.038	-1.987	0.047
Types of poultry occupation	Z9	-0.009	0.009	-1.042	0.298
Marital status	Z10	-0.064	0.032	-1.965	0.049
Membership of farmers association/cooperative society	Z11	-0.042	0.021	-1.922	0.054
Ownership of the farm	Z12	-0.002	0.005	-0.408	0.683
Gender	Z13	-0.04	0.021	-1.877	0.061
Regular medication/vaccination facilities	Z14	-0.388	0.119	-3.240	0.001
Constant	Z0	2.001	0.156	12.809	0.000
Diagnostic statistics					
sigma2		0.67	0.088	7.598	
gamma		0.785	0.100	7.773	
Log Likelihood		-24.661	1.758	-14.026	
Mean TE		0.68			
No. of observations		26			

Source: Author's calculation.

All these findings confirm that there is much room for improving the performance of broiler meat production by centering on improving the technical efficiency and hence the net return of farmers to capital and labour investment.

3.4 Hypothesis Test for Broiler Model Specification

Hypothesis 1, which specified that the inefficiency effects were not stochastic, was strongly rejected, implying that the traditional average response function was not a satisfactory depiction for poultry broiler production, given the specification of the stochastic production frontier and inefficiency models in equations.

Hypothesis 2 relates the existence of inefficiency factor (H_0: $Z_0=Z_1= Z_2= Z_3= Z_4= Z_5=\ldots Z_{14}=0$). Here the null hypothesis was rejected at 1% level, which indicates that in the model inefficiency was present i.e. the inefficiency effects in the model are stochastic.

Hypothesis 3, which specified that the explanatory variables in the model for the inefficiency factors had zero coefficients, was rejected at 1% significance level.

Hypothesis 4 (i.e. $\mu=0$) explored that each farm was operating on the technically efficient frontier and that the systematic and random efficiency in the inefficiency effects were zero. This was rejected in favour of the occurrence of inefficiency effects.

TABLE XIII

HYPOTHESIS TEST FOR BROILER MODEL SPECIFICATION AND STATISTICAL ASSUMPTIONS

Hypothesis	**Likelihood ratio**	**χ^2**	**P value**	**Decision**
1. H_0: $\Upsilon=0$	35.89	13.71	0.008	Reject H_0
2. No inefficiency effect	39.713	18.91	0.000	Reject H_0
[H_0: $Z_0=Z_1= Z_2= Z_3= Z_4= Z_5=\ldots Z_{14}=0$]				
Inefficiency effects in the stochastic production function are not stochastic				
3. No effects of inefficiency factors included				
in the inefficiency model	27.658	16.88	0.002	Reject H_0
[H_0: $Z_1= Z_2= Z_3= Z_4= Z_5=\ldots Z_{14}=0$]				
4. H_0: $\mu=0$	21.88	17.83	0.001	Reject H_0

Source: Author's calculation.

IV. CONCLUSIONS

This paper estimates the technical inefficiency of poultry farms of Bangladesh using the stochastic frontier method. Findings show that large farms are more technically efficient than medium farms and medium farms are more efficient than small farms, suggesting large farms exhibit many types of economies such as economies of scale, economies of management and operation, and economies of buying (inputs) and selling (output). Due to the least per unit cost and reduced managerial cost, in the long run, large farms experience more efficiency than do medium and small farms. Conversely, the smaller the farm, lower the efficiency. The smallholder broiler farmers are characterised by poor production process, low production quantities, and thus slow growth. That is why small farms (and medium farms also) demand special nursing and policy support from the government. It should be kept in mind that small-scale poultry enterprises play a pivotal role for rural people, especially for the poor, women and youth, through generating employment and income. At the same time, locating technical efficiency of large farms below the technical frontier indicates existence of further potential for exploration**.** The heterogeneity in management and production practices applied by farmers with varying socio-economic status may inform the distribution of technical efficiency.

The poultry industry has immense potential for boosting the economic growth of the country as well as ensuring food security. Agricultural land is limited and is rapidly dwindling. A solution to the issue of farmland depletion could be formulation of a sensible and realistic land-use policy. Poultry is most probably the only sector that can grow vertically and produce maximum amount of eggs and chicken meat using minimum land. Rising population and moderate growth of per capita income, urbanisation and high income elasticity of demand are likely to bring an enormous increase in the demand for poultry products. Supply-side constraints, including availability of quality chicks, feed, vaccination as well as policy support, can enormously boost this sector.

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