An application of Data Envelopment Analysis (DEA) to Evaluate Economic Efficiency of Poultry Farms in Bangladesh

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Abstract: This study estimates the technical, allocative and economic efficiency obtained from the Data Envelopment Analysis (DEA) approach using farm level survey data to a sample of 100 poultry farmers in Bangladesh for the year 2007. The results from the DEA approach show that there is substantial technical, allocative and economic inefficiency in poultry production in Bangladesh. The results of the study reveal that under constant return to scale (CRS) and variable returns to scale (VRS) specification, on average, the farms technical, allocative and economic efficiencies were 88%, 70%, 62% and 89%, 73%, 66% respectively. Thus the results indicate that efficiency scores vary substantially across the sampled farms. To explain some of these variations, the efficiency scores were regressed on the farm's human capital variables such as farmer's age, education, main occupation, family members, experience, training received, total farm size and poultry farm size, using a Tobit analysis. The results from the both CRS & VRS approaches indicate that efficiency is significantly influenced by some of the farm's socio-economic factors. This research finding is valuable for policy makers since it may help to guide policies towards increased efficiency.

KEYWORDS: Economic efficiency, DEA, poultry farms

1. Introduction

The economy of Bangladesh is primary dependent on agriculture and about 84 percent of the total population live in rural areas and are directly or indirectly engaged in a wide range of agriculture activities. Agriculture contributes about 22 percent to the country's GDP and about 63

percent of the labor forces are employed in agriculture sector (BBS, 2005). Thus the economic growth and stability depends largely on agricultural development. However, the scope of modern agriculture has been widened significantly.

Under agricultural sector, the poultry sub-sector has, however, a great potential for wide range of reasons. Poultry farming has considerable potentiality for providing income opportunities, reducing malnutrition, generating employment opportunity and alleviating poverty especially for small farmers in Bangladesh. Small farmers can start poultry farm at their homestead area at low cost compare to other livestock farming. Not only that, poultry farming may also provide opportunities for other industries like feed mills, hatcheries etc.

The present farming system of poultry in Bangladesh can be broadly divided into two systems: traditional rural backyard and commercial farming system. Commercial poultry farming system started in 1980 and government's poultry development policy enhanced commercial poultry production which resulted in a spectacular increase in the number of poultry farms. But scavenging poultry farming still dominates the total production, only 14% meat comes from commercial farming system, whereas 86% meat comes from scavenging farming system (BBS, 2005).Within the past few years, poultry meat production has increased significantly in Bangladesh. The growth rates of poultry meat production for the study period, 1971 to 2005, were also increased but not impressive, because the deficit of per capita meat requirement in the country is still having (Table 1) swelling magnitude.

Table 1: Total meat availability and deficiency in Bangladesh

Items	Meat (all)
Total yearly Requirement per capita	7.67 kg/year
Total Per capita availability*	3 kg/year
Total Per capita deficit	4.67 kg/year
Percentage of Deficit	61%

Source: FAOStat (2008)

Under the above circumstances, the poultry sector productivity growth needs to be fostered, through either technological development or an increase in production efficiency, in order to stand the demand pressure and self sufficiency of meat production. To this end, measuring farms efficiency is important as this could be the first logical step in a process that leads to substantial resources utilization. Therefore, the study aims at finding out better use of existing human & capital resources in the poultry production process and to support the policy maker and the government to further take some suitable steps or strategies for removing the farmer's inefficiency in poultry. Thus, the objectives of this research firstly to investigate the poultry farm's technical, allocative and economic efficiency and secondly, to assess the effects of several explanatory variables, i.e. farmers' age, education, family size, main occupation, total land holdings, poultry farm size, experience, training on efficiency of poultry farm in Bangladesh. To fulfill the objectives of the study in this paper, at first, data envelopment analysis (DEA) is used to measures the efficiency level. Then, the Tobit models are estimated as a function of various attributes of the farms within the sample to figure out which aspects of the farms' investment of human and physical resources might be change to improve efficiency (Chavas et al., 2005; Binam et al., 2003).

There have been several studies that have analysed the efficiency of agricultural production in Bangladesh (Kamruzzaman et al, 2006, Wadud and White, 2000), but they have focused on major food crops like rice, wheat etc, and none of them have dealt with the poultry farming in Bangladesh. The study also differs from the previous research in Bangladesh into the estimation and explanation of economic efficiency by including variables that relate to both personal aspects and aspects of the decision-making process of the farmer.

The remainder of the paper is organised as follows. The next section discusses the model specification for DEA and in Section 2.2, sample size and data collection is described. Obtained efficiency scores with the determinants of inefficiency are presented and discussed in Section 3.1 and 3.2. Section 4 provides conclusions.

2.1. Model Specification

Efficiency is the most widely used concept in economics. Efficiency expressed as a combination of technical and allocative efficiencies. Technical efficiency is the ability of the farmer to produce maximum output from a given level of inputs while allocative efficiency measures the ability of the farmer to use inputs in optimal proportions, given input prices. Two efficiency measurement methods are widely used of a decision making unit, one is the parametric Stochastic Frontier Analysis (SFA) and the other method is non-parametric method Data Envelopment Analysis (DEA). The Comprehensive reviews of the two approaches are provided by Lovell (1993), Ali and Seiford (1993), Coelli (1995), Bauer (1990), Fried *et al.* (1993), Bravo-Ureta and Pinheiro (1993). In general, a large number of studies on efficiency measurements argue that a researcher can safely choose any of the methods since there are no significant differences between the estimated results (Coelli, Sandura & Colin, 2002).

The framework for the non-parametric method the Data Envelopment Analysis (DEA) approach was initiated by Farrell (1957) and reformulated as a Mathematical Programming problem by Charnes, Cooper & Rhodes (1978). DEA is a systems approach widely used in management science and economics, in which the relationships between all inputs and outputs are taken into account simultaneously (Yusuf and Malomo, 2007). Given a number of producing units, which are Decision Management Units (DMUs), the DEA producer constructs an efficiency frontier from the sample of producing units. Producing units that are not on the frontier is said to be inefficient. The method enables to find out the relative efficiency of a farm and to examine its position in relation to the optimal situation. The strength of DEA is that it does not require any assumptions about the functional form. The major weakness of DEA is that it is deterministic.

In this paper, we used the DEA method to investigate the economic efficiency of the sample poultry farmers. There are a number of multiple-input single-output production units (the poultry farms) to be evaluated, which are taken as DMUs. Each DMU consumes varying amounts of inputs to produce different level of meat production. In this study input-oriented measures were chosen to reflect local reality, where a decrease in scarce resources (input) use is relevant.

Let us suppose that there are k = 1, …, K DMUs, which in the context of our empirical application are poultry farmers. Each DMU produces m = 1, . . . M outputs using inputs that are both under and beyond a farmer control. Let us further assume that there are data available on K inputs and M outputs for each of N exploitations. The K x N input matrix X and the M x N output matrix Y represent the data for all the firms. An intuitive way to introduce the DEA is via the ratio form. For each farm we would like to obtain a measure of the ratio of all outputs over all inputs. According to Charnes et al. (1978), the optimal weights are obtained by solving following mathematical programming problem (1):

$\text{Max}_{u,v}\,(u'y_i / v'x_i)$

st $u'y_i / v'x_i \leq 1 \qquad j = 1, 2 \ldots, N$

$u, v \geq 0.$ (1)

Where, u is an M x1 vector of output weights and v is a K x 1 vector of input weights. The efficiency measure for the i-th DMU is maximized, subject to the constraints that all efficiency measures must be less than or equal to one. One problem with this particular ratio formulation is that it has an infinite number of solutions. To avoid this, Charnes et al. (1978) proposed the use of a CRS (constant return to scale) equivalent Duality Linear Program which is defined as the following:

$\text{Min}_{\theta,\lambda}\theta$

Subject to $-y_i + Y\lambda \geq 0$

$\theta x_i - X\lambda \geq 0$

$\lambda \geq 0.$ (2)

Where θ is a scalar and λ is a vector of constants, *xi* and *yi*, are column vectors with the input and output data for the i-th farm. *X* is a K by N matrix and *Y* is a M by N matrix with respectively all input and output data for all N farms in the sample. The value θ is a score always lying between zero and one, with a value of one indicating that the farm lies on the frontier and is efficient. An implicit assumption of the model described above is that returns to scale are constant and thus farms are operating at an optimal scale (Fraser and Cordina, 1999). A BCC (Banker et al. (1984) DEA model computes however for a Variable Returns to Scale (VRS) by adding the convexity constraint: $N1' \lambda = 1$, to the CCR model (2) above. Without this convexity constraint, the DEA model will describe a CRS situation.

However, based on the technical and allocative efficiency the economic efficiency can be determined as EE[1]=AE*TE. Allocative efficiency itself is calculated in two steps. First a cost-minimizing vector of input quantities given the input prices is determined using the model from program 3:

$\text{Min}_{xi^*,\lambda}\ w'x_i^*$

Subject to $-y_i + Y\lambda \geq 0$

$x_i^* - X\lambda \geq 0$

$N1'\lambda = 1$

$\lambda \geq 0.$ (3)

where *wi* is a vector of input prices for the i-th farm and *xi** (which is calculated by using linear programming) is the cost-minimizing vector of input quantities for the i-th farm, given the input prices wi and the output levels *yi*. The other symbols are defined the same as in eq 1. The economic efficiency (EE) of the i-th farm is calculated as the ratio of the minimum cost to the observed cost (eq. 3)

EE= w'i xi/ w'i xi*

2.2. Data and Field Survey

The analysis was based on the primary data collected through a comprehensive field survey. A sample of 100 farms was chosen. Secondary data were also collected from the FAOSTAT website and Bangladesh Bureau of Statistics (BBS). The data were composed by Excel and finally it was analysed by a DEA-Solver, e.g. Win4DEAP, and LIMDEP.

[1] Called also "cost efficiency" (Coelli, 1996)

The Gazipur district was selected as study area for commercial poultry farm because it has been declared by government of Bangladesh as poultry region and has a high concentration of poultry farms. A field survey was carried out on 100 commercial poultry farms that were selected randomly from Kaliakoir and Sripur Thanas under Gazipur district. The period of investigation of this study covered one year beginning from January 2007 to December 2007. Data were collected from February 2008 to April 2008.

3.1. Efficiency Measurement

The main costs of poultry farms in Bangladesh are variable costs, which consisted of day old chick, feed, labor, vaccine and medicine, transportation, litter, equipment, housing, land use cost, etc. For the measurement of economic efficiency the inputs used were: (i) human labour (man-days) and wage rate; (ii) Day Old Chicks (cumulative weight) and price of that, and (iii) Feed (kilogram) and price of per kilogram feed, etc. We used these three variables because under all variable costs, these variables are major and cover 75 to 80 percent of the total cost (Begum et al, 2005; Ukil and Poul, 1992; Bhuiyan, 2003; and Uddin, 1999). Besides, others variable data was only found in value term, here for efficiency analysis we used physical term. Output data were also recorded by the cumulative weight of sold bird. The frequency distribution of the efficiency estimates obtained from the DEA frontier and their summary statistics are presented in Table 2. Given the large variability in the computed measures, efficiency scores are clustered into six groups such as 0.00–0.50, 0.51-0.60, 0.61-0.70, 0.71- 0.80, 0.81–0.90, and 0.91–1.00.

Table 2: Frequency distribution of efficiency estimates from the DEA models

Efficiency index (%)	DEA frontier Number of farms					
	CRS			VRS		
	TE	AE	EE	TE	AE	EE
1-50	0	4	15	0	3	6
51-60	0	18	38	0	10	30
61-70	0	35	29	0	32	35
71-80	14	25	13	8	29	20
81-90	44	9	2	45	18	4
90-100	42	9	3	47	8	5
Mean	0.88	0.70	0.62	0.89	0.73	0.66
Standard deviation	0.06	0.12	0.11	0.06	0.12	0.12
Maximum	1	1	1	1	1	1
Minimum	0.73	0.43	0.42	0.75	0.45	0.45

The estimated mean values of technical, allocative and economic efficiency are 88, 70, and 62 per cent for CRS DEA frontier and those are 89, 73, and 66 per cent for VRS DEA frontier. Thus the results of DEA analysis reveal substantial inefficiencies in poultry production. There is a scope for reducing cost in production and hence obtaining output gain through efficiency improvement. In terms of scale economics, 68 farms are characterized by increasing return to scale, 19 farms have constant return to scale and 13 farms are characterized by decreasing return to scale (Table 3). If all farms are using the same technology, then we would expect returns to scale to be increasing for farms with a relatively low output and decreasing return to scale farms with a relatively high output. Constant return to scale would be expected for farms with a output level equal to mean output (Silberberg, 1990). The mean output of the super-optimal scale is larger than the suboptimal as well as optimal scale for the sample poultry farms (Table 3). The results indicate that the optimal output levels overlap a great portion of the suboptimal and super optimal output values.

Table 3: Optimal, suboptimal and super optimal outputs for the poultry farm

Scale	Number of farms	Mean output	Output range
Optimal	19	16395.26	7550-35520
Suboptimal	68	9633.65	5700-19535
Super-optimal	13	15612.15	12330-20390

3.2. Identifying factors of efficiency using Tobit Analysis

After efficiency measurement, the research identifies the factors that influence the farm technical, allocative and scale efficiency using a Tobit analysis. The factors used in this study consist mainly of farm's human capital variables. Human capital variables include farmer's age, farmer's educational background or schooling (no. of years) and total number of family members (family size), farmers occupation that means whether poultry farming is considered as main or subsidiary occupation, total farm size, poultry farm size, experience, training received etc.

In this research, Tobit analysis has been used because the dependent variable, efficiency, is a censored variable with an upper limit of one (Lockheed *et al*., 1981). This Tobit model is employed using DEA method to estimate the factors associated with efficiency with the help of LIMDEP statistical tool. The dependent variable in this model is the initial IE_i calculated by DEA.

$IE_i = \alpha 0 + \alpha 1AG + \alpha 2ED + \alpha 3Ocu + \alpha 4FS + \alpha 5FM + \alpha 6PFS + \alpha 7Tr + \alpha 8Exp + \varepsilon$

Where,

IE_i is the technical, allocative and economic efficiency of poultry farms,

AG is the age of the farmers in years,

ED is the education of the farmers (years)

Ocu is the main occupation of the farmer dummy variables = 1 if poultry farming, = 0 otherwise,

FS is the farm size that is total land holdings in decimal,

FM is the family members in number,

PFS is the poultry farm size in decimal

Tr is the training on poultry framing dummy variable = 1 if farmer received, = 0 otherwise,

Exp is the experience of poultry farming (years)

ε is the error term.

The results show that education is positively and significantly related to farm's technical and scale efficiency. This is expected because the more educated farmers are more likely to be efficient as compared to their less educated counterparts, perhaps as a result of their better skills, access to information and good farm planning.

The production efficiency may also be related to the total farm size. Large farms are often considered more allocative efficient than small farms due to economic advantages concerning the organization and economic knowledge. Empirical evidence, provided by several studies on the relationship between efficiency and the farm size, has also been taken into account (Garcia *et al*., 1982; Byrnes *et al*., 1987).

Another variable, which seems to be related to efficiency, is the size of poultry farm. In case of VRS approach poultry farm size contribute negatively to a higher level of efficiency either. A possible explanation is that here poultry farm size is accounted as land size (in decimal) rather than bird size (number of birds).

Training on poultry farming contributes significantly to a higher level of efficiency. The results indicate that training had a positive and significant effect on poultry farm's technical efficiency.

The level of technical efficiency may increase or discrepancy of resource use from the optimum level may have a chance to reduce by improving management efficiency through training.

The experience dummy is significant and positive in allocative and economic efficiency in CRS approach, and technical and allocative efficiency in VRS approach. A possible explanation is that experienced farmers have more knowledge on their resource & practices, which enables them to resource utilization more efficiently. For instance, commercial poultry farming requires highly technical knowledge to produce chicken efficiently. The highly technical knowledge refers to knowledge of keeping temperatures for rearing poultry birds appropriately. Also, the appropriate timing of feeding, lighting and vaccination are important. A broiler needs different temperatures in different stages of its growth. For example, it needs 35^0 C, 32.2^0 C, 29.4^0 C, 26.6^0 C and 23.7^0 C in the 1^{st}, 2^{nd}, 3^{rd}, 4^{th} and 5^{th} week, respectively. Furthermore appropriate lighting according to the age of the day-old chicks is also important for its growth. Also, feed amount of day-old chicks varies according to growing stage. A day-old chick requires feed everyday by 10 gm, 20 gm, 30gm, and 40 gm, in the 1^{st}, 2^{nd}, 3^{rd} and 4^{th} week, respectively. Finally, a broiler requires 100 gm of feed everyday in 10^{th} week. Timely vaccination of birds is also important for the growth of chicks. So, if the farm owner is experienced then could run poultry business properly and efficiently.

Table 4: Tobit regression analysis of factors associated with inefficiency

Factors	TE	AE	EE
DEA frontiers			
Constant return to scale			
Constant	0.8076***	0.4949***	0.3642***
Age	0.0006	-0.0015**	-0.0007
Education	.0058***	-0.0003	0.0041***
Occupation	. 0190	-.0074	0.0081
Total farm Size (decimal)	-.00003	0.0001***	.0001
Family members	.0019	-0.1046	0.0014
Poultry farm Size	-.0015	-0.0006	0.0421
Training	.0397***	-0.0121	-0.0020*
Experience	-0.0027	0.0415***	0.0359***
Log likelihood	147.54	153.44	154.31
Variable return to scale			
Constant	0.4315***	0.5479***	0.8379***
Age	-0.0005	-0.0011	0.0006
Education	0.0039**	-0.0002	0.0051***
Occupation	-0.0004	-0.0110	0.0138
Total farm Size (decimal)	0.0001	0.0001***	-0.00002
Family members	0.0046	0.0025	0.0024
Poultry farm Size	-0.0088***	-0.0059***	-0.0037
Training	0.0044	-0.1189	0.0267**
Experience	0.0368***	0.0395***	-0.0006
Log likelihood	136.94	154.08	141.51

Note: ***, *, ** indicates 1%, 5%, 10% level of significance

Other factors such as farmer's age, number of family members, main occupation are insignificant to both CRS and VRS technical efficiency in the models.

4. Conclusion

In this study technical, allocative and economic inefficiency of poultry farms of Bangladesh has been estimated by using the Data Envelopment Analysis (DEA) approach and the variation in economic inefficiency is explained using various farm-specific human capital variables. Assessment of efficiency implies considerable amount of technical, allocative and economic inefficiency among the sample farms. The results showed that under constant return to scale (CRS) and variable returns to scale (VRS) specification, technical, allocative and economic efficiencies were 88%, 70%, 62% and 89%, 73%, 66% respectively. That is, under the CRS & VRS DEA approach the sampled farms were 12, 30, 38 percent and 11, 27, 34 per cent respectively, below what could be achieved. The farm households appear to be dominantly increasing returns to scale. The sampled farmers, on average, could increase their poultry production if they could operate at full technical, allocative and economic efficiency levels, given the existing technology. Evaluating factors associated with inefficiency suggests that farmer's educational background, experience, training, farm size, poultry farm size are most statistically significant factors associated with technical, allocative and economic inefficiency. Inefficient farms used an excess amount of inputs on poultry farms in a rural area of Bangladesh. By reducing the excess amount of inputs on one hand and by raising output per farm on the other, their efficiency level can be improved and farmers can be benefited economically. Thus the results of the study give information to policy makers and extension services on how to better aim efforts to improve poultry farm efficiency. This could contribute to compensation of high production cost, hence improve farm revenue, welfare and generally help agricultural as well as economic development.

References

Ali, A. I. and Seiford, L. (1993) The Mathematical Programming Approach to Efficiency Analysis, in (Eds) H. O. Fried, C. A. K. Lovell and S. S. Schmidt, *The Measurement of Productive Efficiency*, pp. 120-59, Oxford University Press, New York

Banker, R. D., Charnes, A., Cooper, W.W., 1984. Some models for estimating technical and scale inefficiencies in Data Envelopment Analysis. Management Science. 30 (9), 1078-1092.

Bauer, P. W. (1990) Recent Developments in the Econometric Estimation of Frontiers, *Journal of Econometrics*, **46**, pp. 39- 56

BBS (2005) *Yearbook of Agricultural Statistics of Bangladesh*, 2005, Planning Division, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka

Begum, I. A., Fumio Osanami and Takumi Kondo (2005) Performance of Vertically Integrated Contract and Independent Poultry Farms in Bangladesh: A comparative study. The Review of Agricultural Economics, Japan, Vol. 61. pp. 101-117

Bhuiyan, H.A. (2003). A Comparative Economic Analysis of Poultry Production Under Supervision of Aftab Bahumukhi Farm and Own Management in Some Selected Areas of Kishorganj District. M.S. thesis, Submitted to the Department of Agricultural Economics, Bangladesh Agricultural University, Mymensingh

Binam, J.N., Sylla, K., Diarra, I., Nyambi, G., (2003). Factors Affecting Technical Efficiency among Coffee Farmers in Côte d'Ivoire: Evidence from the Centre West Region. R&D Management 15, pp. 66-76

Bravo-Ureta, B. E. and Pinheiro, A. E. (1993) Efficiency Analysis of Developing Country Agriculture: A Review of the Frontier Function Literature, *Agricultural and Resource Economics Review*, **22**, pp. 88-101

Byrnes, P., Fare, R., Grosskopt, S. & Kraft, S. (1987) Technical efficiency and size: the case of Illinois grain farmers, European Review of Agricultural Economics, 14, pp. 367–381

Charnes, A., Cooper,W. & Rhodes, E. (1978) Measuring the Efficiency of Decision-Making Units, *European Journal of Operational Research*, 2, pp. 249–444

Chavas, J., Petrie, R., Roth, M., (2005) Farm Household Production Efficiency: Evidence From the Gambia. *American Journal of Agricultural Economics* 87, pp. 160–179

Coelli, T. J. (1995) Recent Developments in Frontier Modelling and Efficiency Measurement, *Australian Journal of Agricultural Economics*, **39**, pp. 219- 45

Coelli, T. J., (1996), A Guide to DEAP Version 2.1: A Data Envelopment Analysis (Computer) Program, CEPA Working Paper No. 8/96, ISBN 1 86389 4969, Department of Econometrics, University of New England, p. 49

Coelli, T. J., 1996. A Guide to DEAP Version 2.1: A Data Envelopment Analysis (Computer) Program, CEPA Working Paper No. 8/96, Department of Econometrics, University of New England.

Coelli, T., Rahman, S. and Thirtle, C., (2002) Technical, Allocative, Cost and Scale Efficiencies in Bangladesh Rice Cultivation: A Non-parametric Approach. *Journal of Agricultural Economics*, 53, pp. 607-626

Coelli, T., Sandura, R. & Colin, T. (2002) Technical, Allocative, Cost and Scale in Bangladesh Rice Production: A Non-parametric Approach. *Agricultural Economics* 53, pp. 607-626

Coelli, T.J.; D. S. P. Rao; and G. E. Battase (1998) *An Introduction to Efficiency and Productivity Analysis*. Boston: Kluwer Academic Publishers

FAO (2008) *FAO stat.* Statistical Database of Food and Agriculture Organization of the United Nations, Rome

Farrell, M. J. (1957) The Measurement of Productive Efficiency, *Journal of the Royal Statistics Society, Series A* (General), Part III, pp. 120–134

Fraser, I., Cordina, D., 1999. An application of data envelopment analysis to irrigated dairy farms in Northern Victoria, Australia. Agricultural Systems. 59, 267–282.

Fried, H. O., Lovell, C. A. K. and Schmidt, S. S. (Eds) (1993) *The Measurement of Productive Efficiency: Techniques and Applications*, Oxford University Press, New York

Garcia, P., Sonka, S. & Yoo, M. (1982) Farm size, Tenure, and Economic Efficiency in a Sample of Illinois Grain Farmers, American Journal of Agricultural Economics, 64, pp. 119–123

Kamruzzaman, M. M. Manos, B. Begum, M. A. A (2007) Evaluation of Economic Efficiency of Wheat Farms in a Region of Bangladesh Under the Input Orientation Model. Journal of the Asia Pacific Economy, v. 11, n. 1, p. 123-142, 2006

Lockheed, M.E., Jamison, D. & Lau, L.J. (1981) Farmer Education and Farm Efficiency: A Survey, *Economic Development and Cultural Change*, 29, pp. 37–76

Lovell, C. A. K. (1993) Production Frontiers and Productive Efficiency in (Eds) H. O. Fried, C. A. K. Lovell and S. S. Schmidt, *The Measurement of Productive Efficiency*, pp. 3-67, Oxford University Press, New York

S.A. Yusuf and O. Malomo (2007) Technical Efficiency of Poultry Egg Production in Ogun State: A Data Envelopment Analysis (DEA) Approach, International Journal of Poultry Science 6 (9) pp. 622-629

Uddin, H. (1999). A Comparative Economic Analysis of Broiler and Layer Production in Some Selected Areas of Sadar Thana in Mymensingh District. M.S. thesis, Submitted to the Department of Agricultural Economics, Bangladesh Agricultural University, Mymensingh

Ukil M.A. and Paul, D.C. (1992). *Problems and Prospects of Broiler Industry.* Conference of Bangladesh Animal Husbandry Association, Dhaka

Wadud, A., and B.White. 2000. From Household Efficiency in Bangladesh: A Comparison of Stochastic Frontier and DEA. *Applied Economics Vol (*32), No. 13 pp. 1665-1673