Cost efficiency of small-scale commercial broiler production in Zambia: A stochastic cost frontier approach

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Abstract
Over the last two decades Zambia has experienced a rapid growth in poultry production and a large share of broiler meat production has been contributed by small scale urban producers. This study aims to estimate the economies of scale and cost efficiency of small scale broiler farmers in Zambia using a Cobb-Douglas cost function and the inefficiency effects model. Data were collected from 90 small scale broiler farmers in the city of Lusaka selected using a snowball sampling method. The results show that cost efficiency scores ranged from 0.76 to 0.99 with a mean of 0.958. The frequency distribution indicate that cost efficiency scores for 10% of the farmers were between 0.78 and 0.89 and the majority (90%) the scores were between 0.9 and 0.99. Thus, most small scale broiler farmers were highly cost efficient in broiler production. For a farmer with the minimum efficiency, she/he could make cost savings of about 24% and yet produce the same level of output using the available technology. The cost inefficiency significantly decreased with age, education and poultry training. Policy implications are that government should encourage young people be efficient poultry producers, enhance farmer's level of education, training on poultry rearing skills including feeds and feeding since feed is a major determinant of broiler production cost. This can be achieved through short term trainings and extension services arranged during weekends and holidays to allow small scale poultry keepers with full-time jobs to participate. The analysis of scale effects found that the small scale broiler farmers were experiencing positive economies of scale and were in stage I and thus a need exists to move them to the more efficient stage II, through increased production of birds and efficient use of feeds.
Key words: Broiler, stochastic frontier model, cost efficiency.

1. Introduction

The poultry industry plays an important role in the Zambian agricultural sector and the national economy. In 2012 the poultry industry contributed 4.8% of agricultural Gross Domestic Product (GDP), 48% of livestock subsector total value added and generated 50,000 permanent jobs (Poultry Association of Zambia (PAZ), 2013). Of total meat consumed in Zambia, poultry meat accounts for 50%, followed by beef at 28%, then pork and fish at 16% and others at 6% (FAOSTAT, 2013).

Poultry production consists of broiler meat production and egg production and both are undertaken by small, medium and large scale commercial operations. Most commercial poultry production is concentrated around the capital Lusaka, the Copperbelt province and major towns with high population densities and high disposal incomes. The poultry industry has witnessed rapid growth since the economic liberalization of Zambia in the early 1990s. Annual poultry meat production more than doubled from 18,890 tonnes in 1990 to more than 43,000 tonnes by 2011 (FAO, 2013). The current annual poultry production consists of 521 million eggs or 41 eggs per capita production and 51 million broilers which is equivalent to 4 broiler chickens consumed per person per annum. The small scale producers account for 60% of total annual broiler production in Zambia (PAZ, 2013).

This growth in chicken meat production has been driven by increased investments which resulted in increased supply of poultry feeds, breeding stock, day old chicks, point of lay birds, equipment and veterinary drugs. The improved investment climate has also attracted many peri-urban middle class residents to supplement their regular income by raising chickens (Saasa et al 1999). Thus small scale backyard broiler production has emerged in areas near urban towns, especially in the City of Lusaka. To these smallholders, broiler and egg production is an important source of additional income, improved household food nutrition and security and a quick return on micro level investment.

The demand for livestock products including poultry meat is expanding in Zambia with increases in population, disposable income and the growing popularity of the fast food service sector which has increased demand for chicken cuts. In an attempt to enhance the performance of the sector and keep pace with the rising demand, the Government of the Republic of Zambia has focused on strategies aimed at increasing productivity, improved animal health and safety, and transformation or commercialization of small and emerging farmers (MACO 2004). Although, these efforts have the potential to contribute to the development of the livestock and poultry

sector, such efforts could be constrained by inefficiency in resource use. In a country like Zambia where farmers face resource constraints, it is necessary to undertake efficiency studies. Efficiency of poultry producers in particular that of small scale broiler producers is no exception and deserves to be studied.
Worldwide efficiency of agriculture is a topical issue; however in Zambia this subject has received little attention. The few Zambian studies include: Mwape (1988), Kabwe (2012), and Chiona (2011). However, none of the mentioned studies has measured efficiency of poultry production in Zambia. Therefore, the objective of this study is estimate farm level cost efficiency and analyse the factors which affect cost efficiency of small scale broiler production in Zambia using stochastic frontier production analysis.

2. Methodology

2.1 Study area and data

Lusaka the capital city of Zambia is located 28^0E and 15^0S, in the central part of Zambia. It is an urban administrative and commercial services centre with a light industry and it is surrounded by farms. It has a population of around 1.5 million people. The public sector is the major employer in this city. The study utilizes primary data obtained from the field survey conducted between June and July in 2010. The data were drawn from 90 small scale backyard broiler producers from three townships namely Kaunda Square Chelston and Avondale in the eastern part of Lusaka. The farmers in the area raise broilers under a deep-litter system from day-old to marketing point taking about of 6-7 weeks to complete the cycle. A sample of 90 broiler farmers was selected consisting of 30 farmers each from Kaunda Square, Chelston and Avondale. The area was chosen due to prominence of small-scale backyard broiler production. In the absence of a register of backyard broiler producers in the area, the respondents were selected for interviews using the snowball sampling method. A structured and pre-tested questionnaire was used for data collection. The data collected included production inputs and output namely: quantities and prices of chicks, feed, veterinary drugs, litter, utilities (water and electricity), transport, and initial capital investment, birds sold and also socio-economic characteristics of the respondents. The data was collected on the most recently completed production cycle. Out of the 90 questionnaires, 69 were useable and were used in this analysis.

2.2 Theoretical framework

The stochastic frontier production function was independently proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977). The stochastic frontier model incorporates a composed error structure with a two sided symmetry that capture random effects outside the control of production unit and one sided inefficiency component. The stochastic frontier model has been widely applied to measure efficiency of agricultural producers in developing and developed countries. Comprehensive reviews of the economic applications of the stochastic frontier approach include Ali and Byerlee (1991); Bravo-Ureta and Antonio (1993) and Ajibefun et al. (2002).
Based on Battese and Coelli (1995), the stochastic frontier cost function model is specified as follows:

$$Ln\, C = g(P_i Y_i, \propto) + (V_i + U_i) \quad i=1,2,\ldots,n$$

Where
C_i = total production cost of the ith farm
g = the functional form;
P_i = vector of input prices incurred by the ith farm.
Y_i = Output of the ith farm in Kg,
α = Vector of parameters to be estimated.
$V_i + U_i$ = composite error term.
V_i refers to random disturbance costs due to factors outside the control of the farmer. It is assumed to be identically and normally distributed mean zero and constant variance as N $(0, \sigma_v)$.
U_i is the one-sided disturbance form representing cost inefficiency and is independent of V_i. Thus, $U_i = 0$ for a farm whose costs lie on the frontier, $U_i > 0$ for farms whose cost is above the frontier and Ui < 0 for farms whose cost is below the frontier. Ui is identically and independent distributed as $N(0, \sigma_U)$. The two error terms are preceded by a positive signs because inefficiencies are always assumed to increase cost.
The frontier cost function is estimated by the Maximum Likelihood technique which yields estimators for $\propto$ and γ,

where $\gamma = \sigma_u^2/\sigma^2$ and $\sigma^2 = \sigma_u^2 + \sigma_v^2$.

The parameter γ measures the total variation of total cost of production from the frontier cost which can be attributed to cost inefficiency (Battese and Corra, 1977). The parameter lies between zero and one that is

$0 \leq \gamma \leq 1$.

The cost efficiency (CE) of an individual farm is defined in terms of the ratio of observed cost (C^b) to the corresponding minimum cost (C^{min}) given the available technology. It is expressed as:

$$\frac{C^b}{C^{min}} = \frac{g(P_i Y_i, \propto) + (V_i + U_i)}{g(P_i Y_i, \propto) + (V_i)} = \exp(U_i)$$

Where the observed cost represents the actual total production cost while the minimum cost represents the frontier total production cost or least cost level. In the literature there are two ways of representing the cost efficiencies. The first approach involves CE with a value of 1 or higher, with 1 defining the cost efficient farm (see Ogandari et al. 2006). The second approach uses CE values that are bounded by 0 and 1 (see Kumbhakar and Lovell, 2000). The Statalist[1] blog has a discussion on this issue. For this study the efficiency scores are bound between 0 and 1. This involved getting a reciprocal of the CE value predicted using STATA for each farm.

2.3 Empirical Model

The Cobb-Douglas functional form is selected for use in this study based on the fact that the methodology requires a function that is self-dual as in the case of the cost function in which this analysis is based. The explicit Cobb-Douglas functional form for the broiler farms in the Study area can be specified as follows:

$$Ln\ C = \propto_0 + \propto_1 LnP_{1i} + \propto_2 LnP_{2i} + \propto_3 LnP_{3i} + \propto_4 LnP_{4i} + \propto_5 LnP_{5i} + \propto_6 LnY_i + (V_i + U_i)$$

Where: C represents the total production cost in Zambian Kwacha (ZMK); P_1 represents the cost of feeds (ZMK); P_2 represents cost of veterinary drugs (ZMK); P_3 represents cost of transport; P_4 represents the cost of utilities (ZMK); and Y_i represents output of broilers (units).

The inefficiency model based on Battese and Coelli (1995) was specified as:

$$U_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i}$$

Z_1= gender of the farmer (male=1, female=0); Z_2= age of the farmer in years; Z_3= household size (persons); Z_4 = number of years in school; Z_5= attended training in poultry rearing (yes=1, no=0). The model was estimated using the frontier routine in STATA version 10.

Economies of scale (or scale effect (SE)) refer to the reduction in cost of production of a given level of output while holding all other input prices constant. The Scale Effect (SE) is mathematically expressed as the inverse of the sum of elasticities with respect to all output included in the regression. Positive economies of scale prevail if SE is greater than 1 and, conversely the diseconomies of scale occur when SE is less than 1. The scale effects and the return to scale effects are equivalent if and only if the product is homothetic, an assumption that applies to the Cobb-Douglas function (Chambers, 1988). If costs increase proportionately with output, there are no economies of scale meaning that there are constant returns to scale (CRT). If costs increases by a greater amount than output, there are diseconomies of scale meaning that there is decreasing returns to scale (DRT). If costs increase by a lesser amount than output, there are positive economies of scale which is also referred to as increasing returns to scale (IRT). Here since the Cobb-Douglas function is used, this assumption is imposed (Ogundari et al. (2006) and Paudel and Matsuoka (2009).

3. Results and discussion

3.1 Descriptive statistics

Table 1 summarizes the socio-economic characteristics of the surveyed small scale broiler farmers in the study area. Majority of the respondents were female. The farmers' age ranged from 28 to 65 years with average age of 46 years. This indicates that most poultry farmers are around mid-age and within the active labour force with around 68 percent of them holding off-farm employment. The farmers have an average of 13.6 years of education, which indicates that most of them have completed high school and 19 percent of farmers have attended a training course on poultry farming. The farmers have an average of 5 years of experience in broiler production which shows that they have not been involved in poultry farming for a very long time. The farmers rely heavily of family labour in broiler production and the average household size has 5.6 persons with a

[1] Statalist@hsphsun2.harvard.edu – Inefficiency measures greater than one from frontier commands. (Accessed January 2014).

minimum of 2 and a maximum of 12 persons per household.

The farmers raised around 300 birds per cycle in their backyards under a deep-litter system and produce an average of 5 batches per year. An operation raising less than 500 birds per cycle qualify to be classified as a small-scale unit (Saasa et al., 1999). The average initial investment or startup capital was ZMK[1]16,500 but ranged from ZMK8, 000 to ZMK22, 000 (refer to Table 1). The average total cost of production stood at ZMK 30,500. Feed cost was the largest expenditure item and accounted for 65% of the total cost of broiler production. The above indicates that broiler production was undertaken mainly by employed, urban residents with a moderate level of education, and the main objective to generate income and supplement employment income.

3.2 Estimates of the stochastic cost frontier model

The parameter estimates of the stochastic frontier Cobb-Douglas cost function, cost inefficiency model and variance diagnostics are presented in Table 2. The sigma square (σ^2) is statistically significant and different from zero at 1% which indicates a good fit and the correctness of the specified distributional form assumed for the composite error term. Gamma (γ) has a value of 0.921, this means that 92.1% of the variation in the cost of broiler production could be attributed to the cost inefficiency in resource use. In addition the Wald Chi-square statistic for joint test of the model indicates that overall, the model is significant ($p<0.01$). The results of the diagnostic variance statistics thus confirm the relevance of the stochastic parametric cost function and maximum likelihood estimation.

The variance inflation factor was estimated to test for presence of multicollinearity among the variables used in the model. The estimated VIF value was 1.74 and since it is less than 10, multicollinearity is not present (Gujarati, 2003).

Table 1: Descriptive statistics of the variables in the stochastic frontier model

Variable	Mean	Standard deviation	Minimum	Maximum
Gender (Male=1, female=0)	0.41	0.49	0.00	1.00
Age (years)	46.45	9.49	28.00	65.00
Education (years)	13.58	2.69	7.00	16.00
Training (yes=1, No=0)	0.19	0.39	0.00	1.00
Household size	5.88	1.78	2.00	12.00
Employed (yes=1, No=0)	0.68	0.47	0.00	1.00
Total production cost (ZMK)	30103.88	7703.83	13550.00	44655.00
Feed cost (ZMK)	19400.00	5749.99	7000.00	29300.00
Drug cost (ZMK)	398.05	105.55	195.00	650.00
Transport cost (ZMK)	2007.98	1026.50	0.10	5000.00
Utilities cost (ZMK)	1304.77	376.99	448.00	2615.00
Day-old chicks (ZMK)	5194.38	1438.80	2100.00	7700.00
Depreciation (ZMK)	1646.38	326.56	800.00	2200.00
Variable cost (ZMK)	28900.00	7864.20	12400.00	44400.00
Output sold per cycle (birds)	284.85	97.79	90.00	487.50

The parameter estimates of the cost function indicate that all the coefficients have the expected positive signs. All variables except cost of drugs are statistically significant at 1% level. The cost of feed has the largest coefficient at 0.765. This implies that feed is the most important component of the cost of broiler production. It is followed by cost of utilities namely water and lightning with a coefficient of 0.115. The feed cost coefficient of 0.765 implies that a one percent increase in the feed cost will lead to 0.765% increase in total broiler production cost, all other factors held constant. For utilities, a one percent increase in cost will cause 0.115%

[1] ZMK refers to Zambian Kwacha, the currency of Zambia. Exchange rate in 2010 was: ZMK 5.00=USD 1.00.

increase in total broiler production cost.

The statistically insignificant coefficient for drugs and medication (0.007) implies that medication costs constitute a meagre component of the total cost of broiler production. It seems as long as there are no major disease outbreaks in the production period drug costs will remain insignificant. Other studies (Helfand (2003) also found that medication cost constitutes the least proportion of operating costs and were in the range of 2-5 percent.
The estimated coefficient for transport cost of 0.017 implies that a one percent increase in transport cost will cause total production cost to increase by 0.017 percent. This shows that transport has less effect on the cost of broiler production compared to feed cost and cost of utilities.

The elasticity of total cost with respect to broiler output is 0.072 which indicates that a 1% increase in broiler output will increase the total production cost by 0.072%. This shows that cost is increasing but at a lower rate than output. The obtained positive coefficients on all the variables in the cost function imply that the cost function monotonically increases in input prices (i.e., increasing input prices in the same proportion).

Table 2: Maximum Likelihood estimates of parameters of the Cobb-Douglas frontier cost function for small scale broiler farmers in Zambia, 2010

Variable	Parameter	Coefficient	Standard Error	T-value	Sig.
Cost Function					
Constant	α_0	2.003	0.426	4.700	0.000
Cost of feed ZMK	α_1	0.765	0.024	31.460	0.000
Cost of drugs ZMK	α_2	0.007	0.018	0.360	0.715
Cost of transport ZMK	α_3	0.017	0.007	2.380	0.017
Cost of Utilities ZMK	α_4	0.115	0.015	7.680	0.000
Broiler Output (Birds)	α_5	0.072	0.021	3.410	0.001
Inefficiency Model					
Constant	δ_0	0.853	3.109	0.270	0.784
Gender (dummy)	δ_1	0.326	0.598	0.550	0.586
Age (years)	δ_2	-0.095	0.052	-1.820	0.068
Household size	δ_3	0.270	0.219	1.230	0.218
Education (years)	δ_4	-0.291	0.149	-1.960	0.050
Training (dummy)	δ_5	-3.896	1.499	-2.600	0.009
Variance Parameters					
Sigma-square	$\sigma^2 = \sigma_u^2 + \sigma_v^2$	0.006	0.002	3.959	0.003
Gamma	$\gamma = \frac{\sigma_u^2}{\sigma^2}$	0.921			
Lambda	$\lambda = \sigma_u / \sigma_v$	3.405			0.011
Log Likelihood function		124.673			
Wald $\chi^2_{(5)}$		3205			0.000
Mean VIF		1.74			

*, **,*** for 10%, 5% and 1% significance level, respectively.

3.3 Inefficiency effects

In the inefficiency model, a coefficient with a negative sign means that the variable decreases cost inefficiency, while a positive sign means that the variable increases cost inefficiency. The results revealed that three out of five variables in the model were statistically significant with a negative effect on cost inefficiency. The significant variables were age of the farmer (p=0.068), years of education (p=0.05), and farmer training in poultry rearing (p=0.009). Gender and household size were found to be statistically insignificant, indicating that differences of gender and household size (a proxy for family labour) have no significant effect on cost efficiency of small scale broiler production in the study area.

The results concerning age of the farmer, suggest that older farmers are more cost efficient than younger farmers. This is consistent with the findings by Todsadee et al. (2012) that older farmers were more technically efficient in broiler production than younger ones.

The negative coefficients for education and poultry training imply that more educated and more trained farmers would be more cost efficient than less educated and less trained farmers. This finding on education is consistent with findings of Huffman (2000) and Dhungana et al. (2004) among others that educated farmers are more likely to be efficient as compared to their less educated counterparts, perhaps as a result of better access to information and good farm planning. Training is an important tool to poultry farmers as it enhances the opportunity to learn improved technologies and needed inputs and services and thus raises productivity. Training is also closely associated and often provided through extension contact. Other studies including Effiong and Umoh (2010) have confirmed that extension contact contributes positively to the enhancement of profit efficiency in egg laying enterprise in Nigeria.

Household size a proxy for family labour and the result shows that it has a positive insignificant coefficient indicating that household size has no effect on cost efficiency in broiler production in the study area. This finding is contrary to studies that have found house size to be significant with either positive or negative sign. The positive coefficient suggests that larger households may utilise family labour to reduce labour costs and create formidable basis for improving technical efficiency (Mubmik and Flinn (1998) and (Ezeh et al., 2012). On the other hand, the negative coefficients could indicate that household size and technical efficiency were negatively related (Bravo-Ureta and Antonio, 1997).

3.4 Distribution of cost efficiency scores

A frequency distribution of the predicted cost efficiency scores is presented in Table 3. The relative frequency in percentages show that more than half (59%) of the farmers have cost efficiency scores between 0.96 and 1.00, followed by more than a third (36%0 with cost efficiency scores between 0.91 and 0.95. The mean cost coefficient was 0.95 with a minimum of 0.76 and a maximum of 0.99. These results indicate that most small-scale farmers in this study are highly cost efficient in broiler production using the available technology.

Table 3: Frequency Distribution of Cost efficiency in Small-Scale Broiler Production in Lusaka District, Zambia

Cost efficiency range	Frequency	Percent
0.75-0.80	1	1.4
0.81-0.85	1	1.4
0.86-0.90	1	1.4
0.91-0.95	25	36.2
0.96-0.99	41	59.4
Total	69	

Mean Cost Efficiency = 0.956; Maximum value = 0.99, Minimum value = 0.75;

3.5 Scale economies

The scale effect among the small scale broiler farmers in the study area was estimated as the inverse coefficient of cost elasticities with respect to the broiler output in number of birds as the only output in this analysis. The SE vale was found to be 13.88 (i.e. 1/0.072 =13.88), which implies that there is a positive economy of scale. The computed value means that 1% increase in the total production costs increased the total broiler production by 13.88%. This indicates the presence of positive economies of scale and means that an average broiler farmer in the area experiences increasing returns to scale, which is in stage I of the production function, an inefficient stage. Stage I of production can be regarded as the sub-optimal stage where fixed resources are abundant relative to variable resources.

4. Conclusion

The study applied a stochastic cost frontier model to estimate cost efficiency and identify determinants of cost inefficiency in small scale broiler production in Zambia. The results showed that broiler output, cost of feed, cost of transport and cost of utilities had statistically significant positive relationship with total cost of broiler production. The cost of feed had the largest coefficient estimate of 0.76, which means that a 10% increase in the cost of feed will lead to a 7.6% increase in the cost of broiler production among the surveyed farmers.

The cost efficiency scores ranged from 0.76 to 0.99 with a mean of 0.95. Majority of farmers had cost efficiency scores occurring within 5% of the cost frontier, and as such most farmers are highly cost efficient. However, for the farmer with the lowest cost efficiency score of 0.76, the findings imply that such a farmer could make cost savings of about 24% in input use and still produce the same level of output given the available technology.

Results from the inefficiency model, showed that cost inefficiency decreased significantly with age, education and poultry training. Gender and household size had no significant effect on cost efficiency of small scale broiler production in the study area. The results suggest that an increase in age, education and poultry training will increase cost efficiency in broiler production. Policy implications are that to enhance cost efficiency among small scale broiler producers in the study area, government should encourage young people to become cost efficient poultry producers, enhance farmer's level of education, training on poultry rearing skills including feeds and feeding since feed is a major determinant of broiler production cost. This can be achieved through short term trainings and extension services arranged during weekends and holidays to allow small scale poultry keepers with full-time jobs to participate.

Furthermore, the famers were experiencing positive economies of scale and were in stage I. There is need to improve the economies of scale and move the farmers into the more efficient stage II which will enable farmers to achieve maximum output at minimum cost of production. This will require small-scale broiler farmers to increase bird numbers in the existing housing space and efficient use of chicken feeds. Expansion of broiler housing units is unlikely due to limited available backyard space in the urban setting. Again, the government is encouraged to pay more attention to farmer education to improve economies of scale among the small-scale broiler farmers in the study area.

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