Technical Efficiency in Swine Production Under Different Waste Management Techniques

Nsikak-Abasi A. Etim[1,*], Elizabeth S. Ebukiba[2], Edet J. Udoh[1] & Esther U. Essang[1]

[1]Department of Agricultural Economics and Extension, University of Uyo, Nigeria

[2]Department of Agricultural Economics, University of Abuja, Nigeria

*Correspondence: Department of Agricultural Economics and Extension, University of Uyo, Nigeria. E-mail: etimbobo@gmail.com

Received: January 3, 2022 Accepted: January 13, 2022 Online Published: January 20, 2022

doi:10.5430/wjss.v9n1p38 URL: https://doi.org/10.5430/wjss.v9n1p38

Abstract

In spite of the enormous benefits derivable from pig production, farmers are yet to fully maximize output due largely to inefficiency in the use of resources. An empirical study was carried out to examine the technical efficiency of resource use in swine production under different waste management strategies. Multistage sampling procedure was employed to select 60 farmers and primary data were obtained with the aid of questionnaire. Using the stochastic production frontier function based on the Cobb- Douglas form, asymptotic parameter estimates were evaluated to describe efficiency determinants. Result revealed that the most vital factors influencing technical efficiency across the pig farms were labour, medication and stocking density whereas the most critical explainers of inefficiency across all the pig farms were farming experience, access to credit and extension contact. The average efficiency for pig farmers that bury, dump and compost waste were 0.87, 0.88 and 0.74 respectively while the mean efficiency across all the pig farms was 0.80. The fact that all the pigs farms had mean efficiencies of less than one is indicative that none of the pig farms reached the frontier threshold in production. Thus, within the context of efficient agricultural production, pig farmers could still increase their output using appropriate technologies and the right resource-mix.

Keywords: efficiency, stochastic, swine, resource-use

1. Introduction

Declining protein intake has been an issue of serious concern and discourse among nutritionists and food policy makers. United Nations (2019) estimated that Nigeria has 206,139,589 million people and this is likely to cause an upsurge in the demand for and consumption of pork coupled with rising economic activities. Tian *et al.,* (2015) corroborated that the consumption of pork has been rising over the years due largely to increasing economic growth and the consequence of this will be reflected in the outpacing of supply by demand (Etim *et al.,* 2020b). Swine production is a substantial income earner to most families particularly in the southern part of Nigeria where pork is consumed by the inhabitants. Commercial pig farming has lots of benefits including the ability of sow to farrow between 8-18 piglets in a single birth, making it one of the most prolific and reproducing livestock globally. With a short gestation period of 4 months, pigs produce 2 litters per year under ideal, management practices. Their ability to grow very fast and convert feed to meat efficiently is encouraging. Regrettably, in spite the enormous benefits of pig production, Mburu *et al*., (2014) posited that resource poor farmers are yet to take full advantage of these and optimize production. Etim and Edet (2013) however, noted that one of the factors limiting farmers ability to maximize output are inefficiency in resource use caused by poverty, limited access to credit and inputs across farms, inter alia.

One way to ensure increased production, enhanced protein intake and ensure that the demand- supply gap caused by rising population is narrowed is by upscaling swine production through efficient use of resources available. Etim and Udoh (2014) suggested that small scale pig farmers need to be judicious in the use of productive resources in order to maximize returns. Earlier and recent empirical studies by Nguyen *et al.,* (2016) and Etim *et al.,*(2020a);(2020b) also posited that since small scale farmers are the initial managers of land and other productive resources, it is important that resources at this level should be put to the best use for optimal production. This study is necessitated on this premise to contribute to efficiency literature and make recommendations that will serve as a guide for policy intervention in the piggery industry. Therefore, the study was carried out to estimate the factors influencing technical efficiency in swine production under different management strategies.

2. Literature Review

2.1 Theoretical Framework

The ability to produce the greatest possible quantity of product from a given set of resources defines efficiency of a firm. The early works of Farrell (1957) revealed two components of firm's efficiency to include technical and allocative efficiency and combinating these two components results in total economic efficiency which is the ability to obtain a given level of output with least quantity of resources measured either as input-conserving oriented technical efficiency or output-expanding oriented technical efficiency (Jondrow *et al,* 1982; Ali 1996). Enormous studies on farm efficiency using frontier approach has been widely carried out by researchers. Frontier is used to describe the concept of maximality where the function sets a boundary to the range of possible observations. Forsund *et al.*, (1980) noted that the observation of points below the production frontier for firms producing below the highest possible output can occur, though there cannot be any point beyond the production frontier given the available technology. Deviations from the frontier are usually attributed to inefficiency and the classification of frontier studies are based on the estimation techniques namely parametric and non-parametric methods (Kalaizandonakes *et al.,*1992). The parametric method can be deterministic, programming and stochastic depending on the specification of the frontier model. Earlier empirical study by Schmidt (1976) have documented that efficiency measures from deterministic models are affected by statistical noise, and thus the need to explore alternative methodology involving the use of the stochastic production frontier models. A critical feature of the stochastic production frontier is the disturbance term which is a composite error consisting of two components; one symmetric, the other one-side component. The symmetric component, V_i captures the random effects due to measurement error, statistical noise and other influences, and is assumed to be normally distributed. The one-sided component U_i, captures randomness under the control of the firm. It gives the deviation from the frontier attributed to inefficiency. It is assumed to be either half-normally distributed or exponentially distributed.

Stochastic frontier production function is defined as

$$Y_i = F\ (X_i;\ \beta)\ \exp\ (V_i - U_i)\ i = 1, 2, ., N \quad (1)$$

Where Y_i is the output of the i^{th} firm; X_i is the corresponding (MX2) vector of inputs; β is a vector of unknown parameter to be estimated; f(.) denotes an appropriate form, V_i is the symmetric error component that accounts for random effects and exogenous shock; while $U_i \leq 0$ is a one sided error component used to measure technical inefficiency.

3. Methodology

3.1 Study Area

The study was conducted in Cross River State of Nigeria. The state lies between latitudes 6°39' and 6°41' North of the Equator and longitude 8°47' and 8°58' East of the Greenwich. The annual precipitation ranges between 2000 – 3000 mm per annum. According to Etim and Ofem (2005), Etim and Udoh (2014), the rains are necessary to effectively carry out agricultural activities throughout the year. The state is bounded by Benue state to the north, Akwa Ibom State to the south, Abia and Ebonyi states to the west and Republic of Cameroon to the East. It occupies 20, 156 km^2 and comprises several ethnic groups including the Efik, the Ejagham, Yakurr, Bahumono, Bette, Yala, Igede, Ukelle, Utukwang [Utugwang] and the Bekwarra. The major foreign languages in the state are English and French while Efik, Bekwarra, and Ejagham are the indigenous languages

3.2 Sampling and Data Collection Procedure

Multistage sampling technique was employed to select the representative swine producers used for the study. First, 2 out of the 3 Agricultural Development Project (ADP) zones were randomly selected to prevent biases. Secondly, 10 blocks per ADP zone were selected to make 20 villages. Thirdly, 3 swine farmers were selected per block to make a total of 60 swine farmers. Data for the study were primary and obtained from 60 swine producers with the aid of questionnaire.

3.3 Model Specification

The study made use of stochastic production frontier that adds hypothesized efficiency determinants into the inefficiency error components (Coelli and Battese, 1996; Etim and Udoh, 2014). The Cobb-Douglas functional form is specified as follow:

Ln (Qty) = β_o + β_1 Ln (Labour) + β_2 Ln (Feed) + β_3 Ln (Drugs)

+ β_4Ln (Capital) + β_5Ln (Stocking Density) + $V_i - U_i$ --- -----------------------------------(1)

Where Qty is the value of swine produced in naira; labour is the labour employed in farm operations measured in mandays; feed is the concentrate fed to the pigs per season in kg; medication is the value of drugs in naira; capital is the depreciation value of the implement used

measured in naira; stocking density measured as number of pigs per square metre

With V_i~N (O, V^2) and

e^{-ui} = e_0 + e_1 (Age) + e_2(Exp) + e_3 (Edu) + e_4 (Asso.) + e_5 (Credit)+ e_6(Ext.) + e_7 (Sex) + e_8 (Household Size) + Z_i -----------------------(2)

Where Age is the age of the farmer (years); Exp is farming experience in years; Edu is the educational level of the farmer in years; Asso. is membership of farmers association (dummy); Credit is access to credit facilities (dummy); Ext is access to technical assistance (dummy); Sex is the sex of the farmer (dummy); and Household Size is the number of persons who share the same dwelling for at least 6 months; Z_i is an error assured to be randomly and normally distributed. The value of unknown coefficients is equations (1) and (2) are jointly estimated by maximizing the likelihood function (Yao and Liu, 1998; Etim and Udoh, 2014).

4. Results and Discussion

4.1 Descriptive Statistics

Table 1 shows the summary statistics of output and explanatory variables used in swine production. The average number of pigs per pen was 14 while the average labour employed is 270 mandays. The mean age of 45 years is suggestive that pig farmers were within active and productive ages.

Table 1. Summary Statistics of Output and Explanatory Variables

Description	Unit	Mean	Range
Output	Naira	60,000	40,000-90,000
Stocking Density	Square metres	14	12-16
Feed	Kilogram	250	180-380
Labour	Mandays	270	150-390
Medication	Naira	12,000	10,000-14,000
Capital	Naira	350,000	250,000-450,000
Age	Years	45	38-60

4.2 Maximum Likelihood Estimate Results

This model was developed by Coelli (1995) and is estimated by the maximum likelihood (ML) technique. The estimates and inefficiency determinants of specified frontier model for all the pig farms are presented in Table 2. The sigma square (0.3036) is statistically significant and different from zero ($p<0.01$) suggesting goodness of fit and the correctness of the specified distribution assumption of the composite error term. Result also revealed that the variance ratio defined as $\lambda = (\sigma u^2/\sigma u^2 + \sigma\ u^2)$ was estimated to be 60.54 percent indicating that the presence of technical inefficiency among swine producers explained about 60.54 percent variation in the output of pigs produced. This confirms one-sided error component showing the inappropriateness in the use of ordinary least square estimation technique and therefore justifying the employment of the maximum likelihood estimation method.

Table 2. Maximum Likelihood Estimates and Inefficiency Function for Pig Farmers That Bury Waste

Variables	Coefficient	Asymptotic t- value
Production Function		
Constant term	0.2420	2.8206**
Labour	0.2315	2.3895**
Feed	0.7498	4.5656***
Drugs and medication	0.1462	4.5656***
Capital	0.1862	2.4411**
Stock density	0.7325	-3.17335***
Explainers of Inefficiency		
Intercept	0.3368	3.3576***
Age	0.1203	-6.8823***
Farming experience	-0.2476	-7.0657***
Education	0.8389	1.5276
Farmers association	-0.6645	-6.6132***
Credit access	-0.1181	-0.3246
Extension contact	-0.1354	-1.3546
Sex	0.1190	6.6683***
Household size	-0.3900	1.5243
Diagnostic Statistics		
Sigma – square δs^2	0.6331	6.3311***
Gamma (λ)	0.5237	1.6536*
Ln (Likelihood)	-0.2881	
LR Test	3.5692	
Quasi Function	1.2864	

Note: All explanatory variables are in natural logarithms. A negative sign of the parameter in the inefficiency function means that the associated variables have a positive effect on technical efficiency and a positive sign indicates the reverse. Asterisks indicate significance *** 1% ** 5% * 10%

The variable feed refers to the supplementary fed to pigs across all the farms. Result indicate that supplementary feed has a positive and significant impact on the technical efficiency across pig farms. In this study, it is apparent that feed is the second most important production resource with an elasticity of 0.3017. This coefficient implies decreasing returns to scale indicating that the local feed industries should be encouraged to produce sufficient feed for farmers who are involved in pig production. Result is consistent with Ma *et al.,* (2018) who found that technical efficiency was positively and significantly influenced by feed use. Finding is also synonymous with Veysset *et al.,* (2015) who found that technical efficiency of beef cattle was positively correlated to feed use.

In this study, labour refers to both physical and mental efforts of man used in piggery operations. Result implies that a unit increase in labour will raise the technical efficiency. The elasticity of 1.2370 is an indication that pig production is highly labour intensive irrespective of the waste management practice adopted and therefore require large number of people to work on the farm. Finding is consistent with Etim and Udoh (2014); Etim *et al.,* (2014); Etim (2014); Etim *et al*., (2020b) who found that technical efficiency across farms labour was positively associated with labour.

In this study, age has a negative sign and significantly impacts on technical inefficiency in the model. This means that younger pig farmers are more receptive to innovations and more technically efficient than older swine farmers. Result is suggestive that although, older farmers are more experienced in managing resources, evaluating situations and taking decisions (Udoh and Etim 2006a; 2006b & Etim and Udoh, 2014), younger farmers on the other hand, are faster adopters of innovations that will raise technical efficiency and output. Finding is contrary to result of Etim (2015) and Etim and Ndaeyo (2020) who found in their study of adoption that older farmers were faster than younger ones in the adoption of new ideas and technologies and were therefore likely to be more efficient in resource use. Result is not in conformity with Nguyen *et al.*, (2015) who found that age was positively associated with efficiency.

The variable, stocking density is negative and significantly related to technical efficiency. This implies that the lower the number of pigs per square meter, the higher the technical efficiency. Finding is synonymous with Khan *et al.,*

(2021) who found that farmers who use lower stocking density had higher yields and were more technically efficient than those with higher stocking density.

Credit was negative and significantly impacts on technical efficiency in all the farms irrespective of the waste management strategy adopted. Result implies that farmers with minimal production barriers in accessing credit would be more technically efficient than those who find it difficult to access credit. Etim *et al.,* (2020b) found that farmers with less stringent constraints in accessing credit facilities, were more timely in purchasing farming inputs due to the removal barriers thereby raising productivity through efficiency. Result is consistent with earlier empirical findings by Philip *et al.,* (2009), Aye and Mungatana (2010), Etim *et al.,* (2013) and Etim and Udoh (2014), Mohammed *et al.,* (2014), Etim *et al.,* (2020b) who found that access to agricultural credit to farmers is important and is positively linked to agricultural productivity and technical efficiency.

Extension contact captures pig farmers access to technical assistance from agricultural extension personnel. The variable is negative and significantly impacts on technical efficiency in all the sampled farms. Result implies that farmers with less restricted access to timely information and technical advise from extension personnel on modern agricultural techniques were more technically efficient than those with more restricted access to technical support from extension personnel. Similar finding by Etim and Okon (2013) and Athukorala **(**2017) agreed that access to agricultural extension services is positively associated with technical efficiency.

Table 3. Maximum Likelihood Estimates and Inefficiency Function for Pig Farmers That Bury Waste

Variables	Coefficient	Asymptotic t- value
Production Function		
Constant term	0.4745	0.7456****
Labour	0.3728	5.6190***
Feed	0.1644	1.7586*
Drugs and medication	0.3291	1.2236*
Capital	0.2014	1.4721
Stock density	0.1784	-6.7524***
Explainers of Inefficiency		
Intercept	0.5573	5.5573***
Age	0.1019	3.0802***
Farming experience	-0.8951	-3.4026***
Education	-0.5177	-27012***
Farmers association	0.3706	1.0760
Credit access	0.1133	1.0760
Extension contact	0.9146	2.9837***
Sex	0.1559	1.1083
Household size	-0.1435	-3.5717***
Diagnostic Statistics		
Sigma – square δs^2	0.8287	8.2867***
Gamma (λ)	0.2261	1.6510
Ln (Likelihood)	-10.2764	
LR Test	8.286	
Quasi Function	1.6510	

Note: All explanatory variables are in natural logarithms. A negative sign of the parameter in the inefficiency function means that the associated variables have a positive effect on technical efficiency and a positive sign indicates the reverse. Asterisks indicate significance *** 1% ** 5% * 10%.

Table 4. Maximum Likelihood Estimates for Pigs Farmers That Compost Waste

Variables	Coefficient	Asymptotic t-value
Production Function		
Constant term	0.8189	8.1593***
Labour	0.5303	7.8046***
Feed	0.1734	2.9764***
Drugs and medication	0.1533	3.8029
Capital	0.1010	1.5224
Stock density	0.5142	-3.8142***
Explainers of Inefficiency		
Intercept	0.6753	6.7525***
Age	-0.3747	-2.8432***
Farming experience	-0.7966	3.4595***
Education	-0.8816	-8.3311***
Membership of farmers association	-0.4863	-4.8495***
Credit access	0.1534	1.4285
Extension contact	-0.9616	-9.5701***
Sex	-0.1652	-1.5414***
Household size	-0.1296	-1.2964
Diagnostic Statistics		
Sigma – square δs^2	0.4639	4.6398***
Gamma (λ)	0.1453	8.0764***
Ln (Likelihood)	24.1326	
LR Test	3.1142	
Quasi Function	1.2411	

Note: All explanatory variables are in natural logarithms. A negative sign of the parameter in the inefficiency function means that the associated variables have a positive effect on technical efficiency and a positive sign indicates the reverse. Asterisks indicate significance *** 1% ** 5% * 10

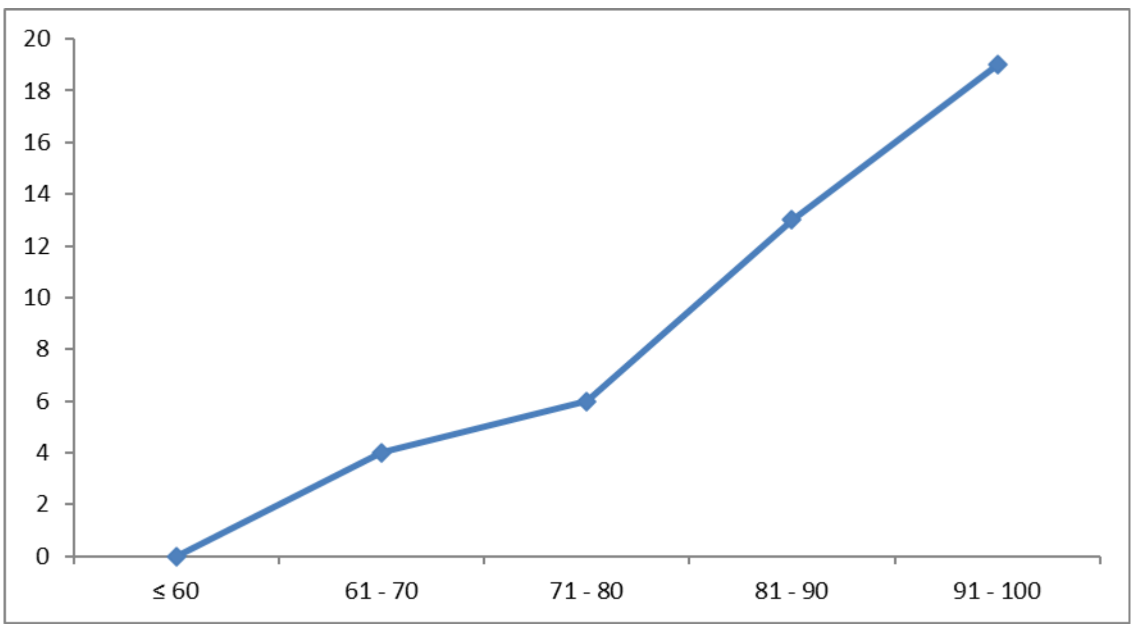
Table 5. Maximum Likelihood Estimation Result for All the Pig Farmers

Variables	Coefficient	Asymptotic t-value
Production Function		
Constant term	0.1035	6.3109***
Labour	1.2370	4.5974***
Feed	0.3017	2.3607**
Drugs and medication	0.1322	1.9597
Capital	0.2994	0.3131
Stock density	0.8008	-3.1632***
Explainers of Inefficiency		
Constant term	0.6186	0.8575
Age	0.7502	2.1475**
Education	0.4161	0.4207
Membership of farmers Association	-0.9354	-1.8618
Credit access	-0.1276	1.1134
Extension contact	-0.9810	-1.8467*
Sex	-0.2967	-2.2683**
Household size	-0.1088	0.1317
Diagnostic Statistics		
Sigma – square δs^2	-0.3036	4.2670***
Gamma (λ)	0.6054	6.4694***
Ln (Likelihood)	30.1516	
LR Test	4.7371	
Quasi Function	1.1072	

Note: All explanatory variables are in natural logarithms. A negative sign of the parameter in the inefficiency function means that the associated variables have a positive effect on technical efficiency and a positive sign indicates the reverse. Asterisks indicate significance *** 1% ** 5% * 10%.

4.3 Resource-Use Efficiency

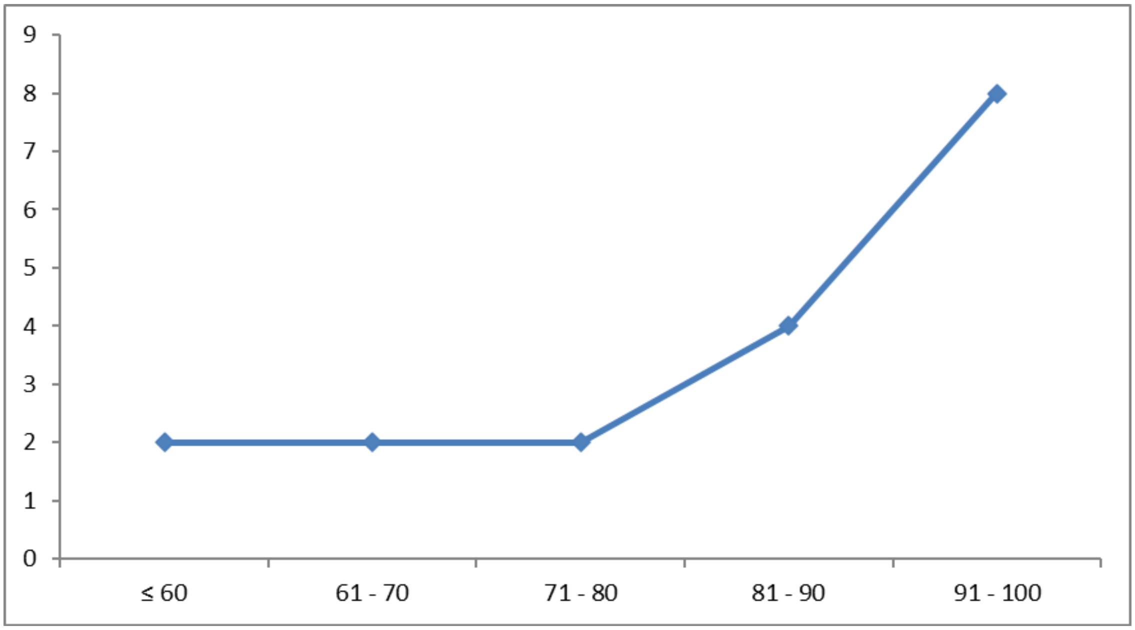
A critical feature of the stochastic production frontier model is it ability to estimate the technical, allocative and economic efficiencies of individual farms. Figures 1, 2 and 3 shows the specific resource use efficiency indices of pig farms under different waste management strategies while figure 4 shows resource use efficiency of all the pig farms irrespective of the waste management strategies adopted. The efficiency indices across the pig farms that bury, dump and compost waste show considerable variation though their technical efficiencies are less than one. This means that none of the sampled pig farms attained frontier threshold thus having the potential to increase efficiency. The fact that mean technical efficiency of all the pig farms in figure 4 is 0.67 implies that within the context of efficient agricultural production, pig farmers could still expand their output using appropriate technologies and the right resource-mix. Result is an indication that farmers are extravagant regarding few marketable outputs due to inefficiency of resource use which explain a significant portion of the overall output variation.(Warnakulasooriya and Athukorala (2016). The inability of the farm to reach their frontier in production may be attributable to multifaceted constraints ranging from production, financial, institutional, socio economic and environmental (Etim *et al.,* 2005, Etim *et al.,*2020b)



Efficiency Class

Mean efficiency = 0.87, Minimum value = 0.67, Maximum value = 0.97

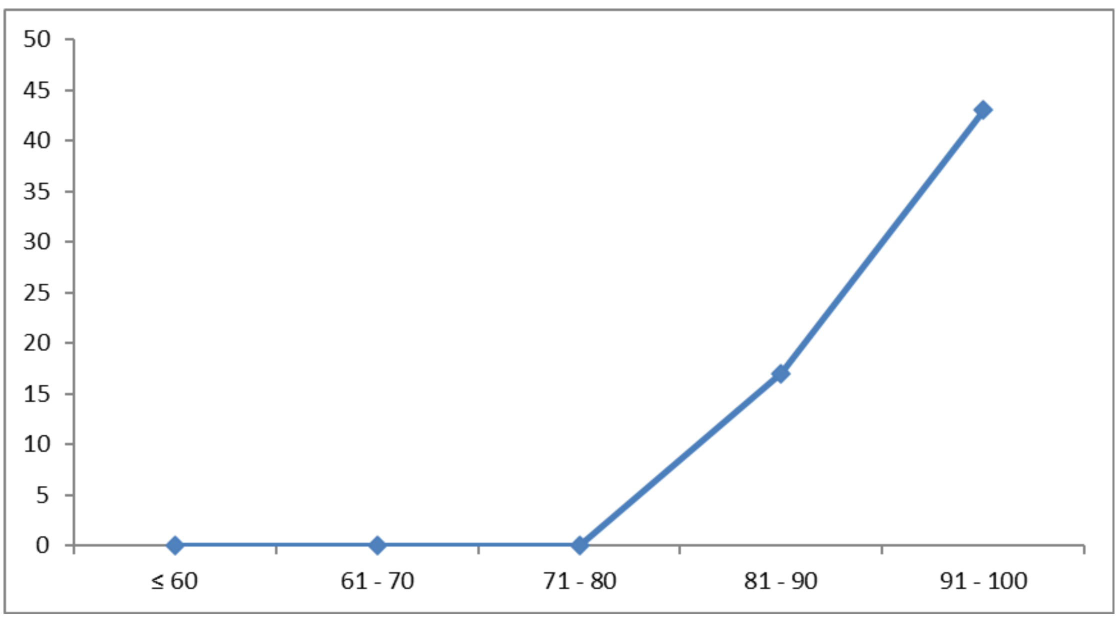
Figure 1. Farm Specific Technical Efficiency for Pig Farms That Bury Waste



Efficiency Class

Mean efficiency = 0.88, Minimum value = 0.12, Maximum value = 0.98

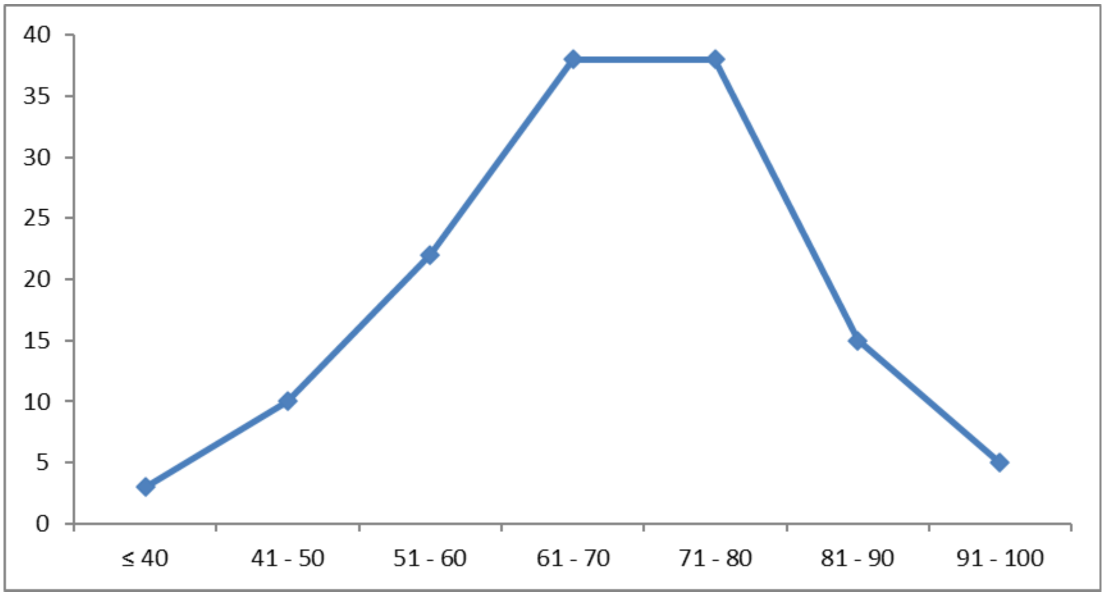
Figure 2. Farm Specific Technical Efficiency for Pig Farms That Dump Waste



Efficiency Class

Mean efficiency = 0.74, Minimum value = 0.99, Maximum value = 0.86

Figure 3. Farm Specific Technical Efficiency for Pig Farms That Compost Waste



Efficiency Class

Mean efficiency = 0.80, Minimum value = 0.17, Maximum value = 0.92

Figure 4. Farm specific Technical Efficiency for All Pig Farms

5. Conclusion

The study estimated farm level technical efficiency of pig farmers. Through the multistage sampling procedure, 120 representative farmers were selected and primary data were obtained using questionnaire. Maximum likelihood estimates of Stochastic production frontier based on Cobb- Douglas production function revealed that none of the pig farms in the study area reached the frontier threshold as their mean efficiencies were less than one. Output from pig farming could increase using available technology and the right resource mix. Policies aimed at increasing farmers access to credit facilities would be rational decision.

References

Ali, M. (1996). Quantifying the socio-economic determinants of sustainable crop production: An application to wheat cultivation in the Tarui of Nepal. *Agricultural Economics, 14*, 45-60. https://doi.org/10.1016/0169-5150(95)01161-7

Athukorala, W. (2017) Identifying the role of agricultural extension services in improving technical efficiency in the paddy rice farming sector in Sri Lanka. *Sri Lanka Journal of Economic Research, 5*(1), 63-77. https://doi.org/10.4038/sljer.v5i1.58

Aye, G. C., & Mungatana, E. D. (2010). Technical Efficiency of Traditional and Hybrid maize farmers in Nigeria: Comparison of alternative approaches. *African Journal of Agricultural Research, 5*(21), 2909-2917.

Coelli, J. T., & Battese, G. (1996). Identification of factors that influence the Technical inefficiency of Indian Farmers. *Australian Journal of Agricultural Economics, 40*(2), 103-128. https://doi.org/10.1111/j.1467-8489.1996.tb00558.x

Etim, N. A. (2014). Are Small Scale Egg Plant Producers Efficient in Resource Use? *American Journal of Agriculture and Forestry*, *2*(4), 154-158. https://doi.org/10.11648/j.ajaf.20140204.18

Etim, N. A. (2015). Adoption of Inorganic Fertilizer by Urban Crop Farmers in Akwa Ibom State, Nigeria. *American Journal of Experimental Agriculture*, *5*(5), 466-474. https://doi.org/10.9734/AJEA/2015/11553

Etim, N. A., & G. E. Edet (2013). Constraints of the Nigerian Agricultural Sector: A Review. *British Journal of Science*, *10*(1), 22-32.

Etim, N. A., & Ndaeyo, N. U. (2020). Adoption of Climate Smart Agricultural Practices by Rice Farmers in Akwa Ibom State, Nigeria. *Journal La Lifesci, 1*(4), 20-30. https://doi.org/10.37899/journallalifesci.v1i4.203

Etim, N. A., & Ofem, B. (2005). Urban farming and Household Waste Management in Uyo Urban. Implications for Environmental Harmony. *Nigerian Journal of Agriculture, Food and Environment*, *2*(2), 74-80.

Etim, N. A., & Okon, S. (2013). Sources of Technical Efficiency among Subsistence Maize Farmers in Uyo, Nigeria. *Journal of Agricultural and Food Science, 1*(4), 48-53.

Etim, N. A., & Udoh, E. J. (2014). Identifying Sources of Efficiency Among Resource Poor Indigenous Vegetable Farmers in Uyo, Nigeria. *International Journal of Food and Agricultural Economics, 2*(1), 33-39.

Etim, N. A., Etim, N. N., & Mohammed, J. (2020a). Resource Use in Deep Litter Poultry System: Implications for Urban Food Security. *International Journal of Technology and Management Research, 3*, 38-44

Etim, N. A., Etim, N. N., & Offiong, E. E. A. (2014). Estimation of Efficiency in Small Scale Pig Production. *European International Journal of Science and Technology*, *3*(6), 111-118.

Etim, N. A., Etim, N. N., & Thompson, D. (2020b). Estimation of Farm Level Efficiency in Fish Production: Implications for Food Security in Akwa Ibom State, Nigeria. *AKSU Journal of Agricultural Economics 3*(2), 1-7.

Etim, N. A., Thompson, D., & Onyenweaku, C. E. (2013). Measuring Efficiency of Yam (Dioscorea spp) Production among Resource Poor Farmers in Rural Nigeria. *Journal of Agricultural and Food Sciences, 1*(3), 42-47.

Etim, N. A., Udoh, E. J., & Awoyemi, T. T. (2005). Measuring Technical Efficiency of Urban Farms in Uyo Metropolis. *Global Journal of Agricultural Sciences, 4*(1), 91-95. https://doi.org/10.4314/gjass.v4i1.2248

Farrel, M. (1957). The measurement of productive efficiency. *Journal of Royal Statistical Society, ACXX*(Part 3), 253-90. https://doi.org/10.2307/2343100

Forsund, F. R., C.A.K. Lovell & P. Schmidt. (1980). A survey of frontier production functions and their relationships to efficiency measurement. *Journal of econometrics, 13*, 5-25. https://doi.org/10.1016/0304-4076(80)90040-8

Jondrow, J. C. A., L. S. Lovell & P. S. Schmidt. (1982). On the Estimation of Technical Inefficiency in the Stochastic Frontier Production Function Model. *Journal of Econometrics, 19*, 233-8. https://doi.org/10.1016/0304-4076(82)90004-5

Kalaitzandonakes, N. G., W. Shua Xiang & M. Jianahun. (1992). Relationship between Technical Efficiency and Farm size revisited. *Canadian Journal of Agricultural Economics, 40*, 427-42. https://doi.org/10.1111/j.1744-7976.1992.tb03705.x

Khan, M. A., Begum, R., Nielson, R., & Hoff, A. (2021). Production risk, technical efficiency and input use nexus: Lessons from Bangladesh aquaculture. *Journal of the World Aquaculture Society, 52*(1), 57-72. https://doi.org/10.1111/jwas.12767

Ma, W., Bucknell, K., & Fenwick, A. (2018). Feed use intensification and technical efficiency of dairy farms in New Zealand. Australian *Journal of Agricultural and Resource Economics, 00*, 1-9. https://doi.org/10.1111/1467-8489.12283

Mburu, S., Ackello-Ogutu, C., & Mulwa, R. (2014). Analysis of Economic Efficiency and Farm size. A case study of Wheat Farmers in Nakuru District, Kenya. *Economics Research International, 3*, 1-10. https://doi.org/10.1155/2014/802706

Mohammed, S. T., Glide, A. A., Shettima, B. G., & Umorun, M. Y. (2014). Resource – Use efficiency of Male and Female Fish Farmers in Maiduguri: A Comparative Analysis. *Nigerian Journal of Fisheries and Aqua Culture, 2*(1), 6-14.

Nguyen, N. H., Beeton, R. J., & Halog, A. (2015). Firm's Characteristics and its adaptive capacity in response to environmental requirements: An empirical study of Vietnam's textile and garment SMEs. *International Journal of Environment and Sustainability, 4*, 1-18. https://doi.org/10.24102/ijes.v4i4.566

Nguyen, T. L., Nanseki, T., & Chomei, Y. (2016). Technical Efficiency and its determinants in Household Pig Production in Vietnam: A DEA Approach. *Japanese Journal of Rural Econs*, *18*, 56-61.

Philip, D. Nkonya, E., Pender, J., & Oni, O. A. (2009). C*onstraints to Increasing Agricultural Productivity in Nigeria: A Review*. Nigeria Strategy Support Programme Paper No. NSSP 006. International Food Policy Research Institute.

Schmidt, P. (1976). On the Statistical Estimation of Parametric Frontier Production Functions. *The Review of Economics and Statistics, 58*, 238-239. https://doi.org/10.2307/1924032

Tian, X., Sun, F., & Zhou, Y. (2015). Technical Efficiency and its determinants in China's hog Production. *Journal of Integrative Agriculture, 14*(6), 1057-1068. https://doi.org/10.1016/S2095-3119(14)60989-8

Udoh, E. J., & Etim, N. A. (2006a). Estimating technical Efficiency of Waterleaf Production in a Tropical Region. *Journal of Vegetable Science, 12*(3), 5-13. https://doi.org/10.1300/J484v12n03_02

Udoh, E. J., & Etim, N. A. (2006b). Cocoyam Farms in Akwa Ibom State, Nigeria: A Stochastic Production Approach. *Journal of Substantial Development in Agriculture and Environment*, *2*, 41-28.

Udoh, E. J., & Etim, N. A. (2008). Measurement of Farm – Level Efficiency of Water-Leaf (*Talinum triangulare*) Production Among City Farmers in Akwa Ibom State, Nigeria. *Journal of Sustainable Development in Agriculture and Environment*, *3*(2), 47-54.

United Nations (2019). United Nations Population Division, Department of Economic and Social Affairs. World Population Prospects 2019 Revision. https://doi.org/10.18356/13bf5476-en

Veysset, P., Lherm, M., Roulenc, M., Troquier, C., & Benin, D. (2015). Productivity and Technical Efficiency of Suckler beef Production Systems: Trends for the period 1990 to 2012. *Animal, 9*(12), 2050-2059. https://doi.org/10.1017/S1751731115002013

Warnakulasooriya, H. U., & Athukorala, W. (2016). Productive efficiency of rice farming under rainfed conditions in Gampaha and Kalutara districts of Sri Lanka. *Sri Lanka Journal of Food and Agriculture, 2*(1), 55-68. https://doi.org/10.4038/sljfa.v2i1.25

Yao, S., & Liu, Z. (1998). Determinant of Grain Production and Technical Efficiency in China. *Journal of Agricultural Economics*, *49*, 171-84. https://doi.org/10.1111/j.1477-9552.1998.tb01262.x