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TECHNICAL EFFICIENCY OF YAM FARMERS IN NIGERIA: A METAFRONTIER APPROACH

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Abstract
Nigerian food producers are predominantly resource-constrained poor farmers, who are the most food insecure. It is crucial to optimize the use of the limited resources available for their performance improvement. Efficient management of the accessible resources will contribute to farmer performance enhancement. This paper investigates the technical efficiency of yam farmers and the existence of environment-technology gap among yam farmers in Nigeria. Cross-sectional data was collected from 360 farmers in Nigeria in 2013. Stochastic frontier analysis was used to estimate the technical efficiency of farmers and the determinants of yam output in Nigeria. Metafrontier analysis was performed to evaluate the environment-metatechnology ratio. The stochastic frontier analysis shows that Nigerian yam farmers have a high mean technical efficiency estimate (0.86). Nevertheless, on Average, they are not fully efficient in yam production. There is room for farmers' technical efficiency improvement in Nigeria. This investigation also indicates that yam production is affected by farm size, quantity of planting material and labour. The result of the metafrontier analysis reveals the presence of an environment-technology gap among farmers in Nigeria. Benue and Ondo States have more favourable environments for yam production. Enugu yam farmers are operating in a more restrictive environment. From this research, there are two key recommendations for yam production in Nigeria; further research is desirable in developing better technologies and farming systems suitable for yam production in the diverse environmental conditions in Nigeria, and farm-level improvements can be gained from an increase in farm size, increasing the quantity of planting material and improving the labour input (the use of labour-saving devices).

Keyword: Yam production, technical efficiency, metafrontier, stochastic frontier analysis

Introduction
Global poverty and food insecurity can be attributed to poor performance of the agricultural sector in the developing countries. The agricultural sectors of these countries are dominated by small-scale resource-constrained farmers with low levels of production. These farmers are the majority of the world's poor and food insecure (FAO *et al*., 2015). To address global food insecurity and poverty, it is appropriate to improve the performance of these farmers. Optimizing the use of the limited resources available is imperative for farmer performance and wellbeing improvement. Improving farmers' performance with the limited resources available to them will depend mainly on how efficiently the resources are managed. Increased efficiency among farmers, *ceteris paribus*, would contribute to wellbeing improvement. Different farmers using the same input levels do not perform exactly the same. This prompts three questions. Why is there a difference in performance of farmers at the same scale of production? What are some farmers doing to be more efficient? What factors influence their performance? Efficiency studies enable researchers to test the presence of and level of inefficiency in production (Ajibefun, 2003). Farmer operating environments and the technologies they use differ. There could be an environment-technology gap (ETG), gap in performance between firms due to differences in environmental conditions and technology. Comparing the efficiency of farmers without considering the ETG may introduce bias in the efficiency estimates. Yam contributes to wealth and food security of the people of sub-Saharan Africa (Ikeh *et al*., 2012). However, its global productivity is declining (O'Sullivan, 2010). This, coupled with increased demand, has resulted in increases in its price (Ikeh *et al*., 2012). It is vital to investigate ways of boosting yam

production to meet the increasing demand and improve farmers' wellbeing. Improvement in yam production in Nigeria would contribute to poverty alleviation and food security in the country. This research suggests methods of improving the performance of the White yam (henceforth yam, its common name in Nigeria) farmers in Nigeria. The potential outcomes of this study are improvement in yam production systems, increased food production and reduced poverty in Nigeria.

Methodology

This study was conducted in Nigeria, the leading yam producer in the world, which is located in West Africa. Geographically, Nigeria lies between longitude $3^0$and 14^0 E and latitude 4^0 and 14^0N (NBS, 2010). It is consists of 36 States and the Federal Capital Territory. Figure 1 is the map of Nigeria States by yam production in '000 metric tons. The top yam-producing States of Nigeria include Benue, Taraba, Enugu, Niger, Kaduna, Cross River, Nassarawa, Ondo, Ekiti, Kogi, Oyo, and Delta. Benue has the highest yam production than the other States. A multi-stage sampling technique was adopted in collecting cross-sectional data from yam farmers in top yam-producing areas of Nigeria. The first stage involved a random selection of three leading yam - producing agro-ecological zones, the agro-ecological zones selected were guinea savannah, tropical rainforest with derived savannah, and low land rainforest with sub savannah. The second stage involved a random selection of three States producing a minimum of 1.2 million metric tonnes of yam per annum from the zones. The selected States were Benue, Enugu and Ondo, which are located in different agro-ecological zones. Farmers in these States use different techniques for yam production (yam is produced mainly without stakes in Benue, yam is staked in Enugu and mounds are usually larger than those of Benue and Ondo States, yams are also staked in Ondo). The third stage involved a random selection of two major yam producing Local Government Areas (LGAs) from each State– the major yam producing LGAs were identified with the assistance of ADPs. The LGAs selected were Buruku and Katsina-Ala in Benue State, Nkanu-East and Uzo-Uwani in Enugu State, and Owo and Ose in Ondo State. The target population were yam farmers in the selected States. A representative sample was used since it would be costly and time consuming to sample the entire population of yam farmers in the study area. The sampling framework is unavailable due to inadequate records. Therefore, Nigerian researchers use a population of one hundred and twenty respondents as a good representation of a State (for instance, Amaefula *et al*., 2010). Data used for this analysis was derived from household survey conducted between September to December, 2013. Data were extracted from yam farmers who are involve in decision making. The survey instrument was administered in the LGAs based on availability of respondents. Data were extracted from randomly selected four hundred and eleven respondents (a minimum of sixty yam farmers from each LGA) by using a well-structured questionnaire; respondents with incomplete information were excluded. Information obtained from three hundred and sixty (360) was used for the study. Translog stochastic function was estimated for yam in Nigeria and the individual States. The technical efficiency (TE) of yam farmers was estimated by using Frontier 4.1c analytical software. The TE of the farmers was tested for the presence of ETG. The metafrontier analysis was performed to determine the environment-metatechnology ratio (EMTR) with Shazam software following (O' Donnell *et al*. ''–'). The standard error for metafrontier production function was estimated using parametric bootstrapping (Otieno, 2011; Villano *et al*., 2012).Translog production function for estimation of production factors is specified as:

$$\text{Log}Y_i = b_0 + \sum_{k=1}^{5} b_k \log X_{ik} + 0.5 \sum_{k=1}^{5} \sum_{m=1}^{5} b_{km} \log X_{ik} \log X_{im} + v_I - u_i \quad \text{.......}(1)$$

Where *Yi* = yam output of i^{th} farmer in kg, X_{ik} are vectors of inputs where X_1 = farm size in hectares, X_2 = labour in Man-days, X_3 = fertilizer used in kg, X_4 = seed yam used in kg, X_5 = depreciated cost of capital, and v_i is the random error not under the control of the farmer. The *ui* captures technical inefficiency relative to stochastic frontier, and b_0 and b_k are estimated parameters. Note that log is logarithm notation.

Results and Discussion

Determinants of yam production

Results for the translog production function indicate that farm size, quantity of planting material and labour are the significant determinants of yam output in Nigeria (Table 1). The diagnostic statistics for all frontiers were significant except the variance ratio (γ) and LR test for Ondo. From the analysis, farm size had a positive relationship with output in all the frontiers, except in Ondo and was significant at 1% probability level. This implies that yam output increases with increase in farm size. This supports a priori expectation of increasing marginal productivity of farm size. It also confirms the findings of (Anyaegbunam *et al*., 2016; Ohajianya *et al*., 2014). As expected, farmers who had large farms produce more yams than those who had small ones. The Table also shows that doubling farm size would boost yam production in Nigeria, especially in Enugu and Ondo. There would be more than proportionate increase in output with increase in farm size in these areas. It is unadvisable for farmers in Benue to double farm size at the current level of technology (this would lead to a reduction in marginal productivity of farm size). Increased farm size would boost yam output in Nigeria. It is essential for Nigerian yam farmers to increase their scale of production in order to boost yam production in the country.

Quantity of planting material significantly influences yam output in all frontiers. Its coefficient was positive in all the frontiers. This shows that yam output increases with quantity of planting material. Increased quantity of planting material would boost yam production in Nigeria. This agrees with a priori expectation that there would be a marginal increase in output accruing from the additional planting material used; and (Mariano *et* *al*., 2010) who observed a positive relationship between seed and rice output in the Philippines. Farmers are advised to increase the quantity of planting material they use. The coefficient of planting material was highest in Ondo and lowest in Benue. This suggests that there would be more positive output response to increase in quantity of planting material in Ondo than in other States. The Table further illustrates that doubling the quantity of planting material in Nigeria and its States would lead to a further increase in its coefficient except in Ondo. This supports that it is crucial to increase the quantity of planting material to boost yam output in Nigeria. Although increasing quantity of planting material will boost yam output in Ondo, it is unadvisable for farmers to double the quantity of planting material in the State.

The result also shows that labour is a significant determinant of yam output in Nigeria, except in Benue State. It had positive coefficients in all the frontiers; indicating that output increases with the use of more labour for yam production. This supports the findings of Backman *et al*. (2011). This investigation contradicts Ashagidigbi *et al*. (2011) and Amaefula *et al*. (2009) who reported a negative correlation between labour and production. The coefficient of labour was higher than those of other variables in Ondo. This implies that output responded more to labour than to other inputs in the State. Increasing labour is vital for output maximization in Ondo. The Table further reveals that doubling labour would lead to a more than proportionate increase in output in Ondo. This confirms that it is crucial to increase labour for yam production in Ondo. Labour is essential for output maximization in Nigeria. Farmers are underutilizing labour in the country, particularly in Ondo. Underutilization of labour could be as a result of unavailability of work-force or high cost of labour in the rural areas, which prevent farmers from employing sufficient labour for yam production. Labour could be augmented with labour saving devices. Farmers could use simple and affordable machinery for yam production to improve their performance.

The investigation also indicates that the coefficient of variance ratio was highest in Ondo State (0.97). This indicates that 97% of the total variation in output was due to inefficiency in Ondo. Benue had the lowest variance ratio (0.78), meaning that 78% of the total variation in output in Benue State was due to inefficiency. The factors influencing yam production in Nigeria were also determined from the metafrontier analysis. The analysis was performed with Shazam 11.1 software. Similar to Nigeria (Pooled) frontier, the MPF supports that farm size, planting material and labour significantly influence yam output in Nigeria. They also had positive coefficients and were significant at 1% probability level.26

Technical efficiency estimates for yam farmers

TE for yam production is high in Nigeria; nevertheless, there exist some level of inefficiency among farmers in the country. The stochastic frontier estimates of TE of yam farmers are presented in Table 2**.** The result establishes a high TE estimate for yam in Nigeria. Majority of yam farmers in Nigeria had TE of above 0.80. The mean TE for yam farmers in Nigeria was 0.86. This shows that Nigerian yam farmers are 86% efficient. This confirms Mekonnem *et al*. (2012) who reported a mean TE estimate of 86% for agriculture in developing countries. Some level of inefficiency exists among the farmers in Nigeria. There is room for efficiency improvement in Nigeria. A high TE estimate indicates the need to focus on investments that shift the production frontier outwards. Benue State outperformed those in other States relative to environment and technology available in the States. The State had the highest mean TE (0.91). A mean TE value of 0.91 reported for Benue implies that an average farmer in the State was 91% efficient with respect to the prevailing environmental conditions and the technology available in the State. Most farmers in Benue had TE above 0.90. The maximum TE estimate for Benue State was 0.9. The most technically efficient farmer in Benue State was97% efficient. Benue also had the highest minimum TE. There was a slight variation in TE in Benue State. This shows that yam farmers in Benue State were at par in yam production. They performed almost similar relative to the technology and environmental conditions. This could mean a less diverse environment/technology and similar yam production technique in the State. From the Table, Ondo State had high TE estimates. Most yam farmers in the State had TE of above 0.90. The State had a mean TE value of 0.85, indicating that an average farmer in Ondo was 85% efficient. Ondo State had the highest maximum TE (0.99); the most technically efficient farmer in Nigeria was 99% efficient and from Ondo. The State had a high variation in TE estimates which could be attributed to diverse environment and gap in the use of technology in the States. Performance improvement could be achieved by technology adoption in Ondo State. Enugu was the less technically efficient State relative to the technology available in the State; Enugu State had the lowest TE estimate. An average farmer in Enugu State was 80% efficient relative to the technology available in the State. Enugu State had the lowest maximum and minimum TE estimates of 0.96 and 0.43 respectively. In Enugu State, the most technically efficient farmer was 96% efficient, while the least technically efficient yam farmer was 43% efficient. Majority of the yam farmers in Enugu had efficiency between 0.81 and 0.90. The variation in TE score was highest in Enugu. This suggests that farmers in the State were not at par in yam production. The low mean TE reported for Enugu could be due to a high variation in TE score within the State. This research suggests the adoption of improved technologies to close the TE gap in Enugu State. LR test was performed to test the hypothesis that yam farmers are technically efficient. Table 3 presents the result of the test of hypothesis. Surprisingly, despite the high efficiency estimates observed in Nigeria, the result shows that Nigerian yam farmers are not fully technically efficient. The null hypothesis that farmers are technically efficiency was rejected for Enugu, Ondo and the pooled frontiers. Benue farmers were technically efficient in yam production.

Environment-technology gap across regions

Yam production differs among States in Nigeria. Table 4 displays the test of hypothesis that the group frontiers are similar. The hypothesis that the environment/technology for yam production is the same between States was tested using generalized likelihood ratio. The generalized likelihood that the group frontiers are the same was LR = 97.66 and significant at 1% (using chi-squared distribution at 40 degree of freedom). The hypothesis that the States frontiers are the same was rejected. Therefore, the pooled frontier is inappropriate to estimate the TE of farmers in the country due to the presence of ETG. This justifies the estimation of metafrontier production function (MPF) for yam in Nigeria. The metafrontier analysis was used to determine the interference of the technology/environment on farmer performance in Nigeria. Table 4 displays the TE and EMTR estimates for yam farmers in Nigeria. The metafrontier result demonstrates that there exists gap in technology/environment between regions in Nigeria. However, some farmers in all the States were at par in yam production relative to the environment/technology defined by the metafrontier. The maximum EMTRs for all the States were equal to one; all the frontiers were tangent to the metafrontier. This shows that some farmers are performing optimally in yam production in all the States. Optimal use of resources implies that there is need for technology advancement. Enugu yam farmers were closer to the metafrontier than those of other States. The State had the highest mean EMTR (0.91). This suggests that an average yam farmer in Enugu produces 91% of their potential output using the same input and technology presented by the metafrontier. It can be inferred from this evaluation that eliminating the effect of the environment and/or technology on the TE of farmers, an average yam farmer in Enugu outperforms those in other States. This shows that Enugu has unfavourable environment/technology for yam production. On average, Enugu farmers are optimizing the use of inputs but the constraining environmental conditions/technology prevents the farmers from attaining a high regional TE in yam production. The State had a high deviation in EMTR which could imply a more diverse environment/technology in the State. Improving the environmental conditions/technology for yam production in Enugu and adoption of new technology will enhance farmer performance and boost yam production in the State. An average farmer in Benue State could produce 89% of their potential output with the technology defined by the metafrontier. The minimum EMTRs were similar for Benue and Enugu (0.58). This indicates that the lowest performing farmers in Benue and Enugu performed equally, with respect to the technology defined by the metafriontier. The deviation in EMTR was less in Benue. From this, it can be deduced that eliminating the impact of technology on the performance of yam farmers, Benue will be less technically efficient than those of Enugu. This confirms that adopting improved technology and improving the farming conditions in Enugu will enhance the performance of yam farmers in the State. This research indicates that Ondo yam farmers performed worst in yam production relative to the technology defined by the metafrontier. Yam farmers in the State are further from the metafrontier. This State had the lowest mean EMTR. This implies that eliminating the interference of the environment and technology on farmer performance, it would be the worst performing State. The maximum output that could be produced by an average yam farmer in Ondo using inputs available in the State and the technology in Nigeria is 86% of the maximum output that could be produced using the same input and the technology presented by the metafrontier. Ondo State had the lowest minimum EMTR (0.47); this shows that the worst performing farmers with respect to the technology defined by the metafrontier was from Ondo State. There was more deviation in EMTR in Ondo. This can be interpreted that there is a notable difference in the environment /technology in Ondo State. Some farmers in Ondo could explore the technology /environment available in the State than others. It could also mean that there is a more diverse environment/technology for yam production in Ondo. There is sub-optimal utilization of inputs in Ondo. Optimising the use of inputs and adoption of improved technologies will contribute to performance improvement in Ondo State.

The result of the analysis reveals that Benue and Ondo farmers outperformed those in Enugu on the Pooled frontier. Benue and Ondo State had similar mean TE-POOL (0.87) which was greater than that of Enugu (0.83). The implication of this is that an average yam farmers in Benue and Ondo State performed equally and more than those in Enugu. The maximum TE-POOL was similar for all the State, indicating that the most technically efficient farmers in all the States performed equally. It can be construed from this that some farmers in Enugu State have ideal environment / technology for yam production in Nigeria. The Table further illustrates that the MPF gave the lowest estimates of TE in all the States. Benue had the highest mean TE-MF score (0.80). This shows that on average, Benue produced 80% of the maximum output that could be produced using the input level defined by the metafrontier. Enugu and Ondo States had similar mean TE-MF (0.73). Mean farmers in Enugu and Ondo States produced 73% of their maximum output with the technology defined by the metafrontier. This implies that eliminating the effect of the environment/technology on farmers' performance, and an average yam farmer in Enugu will perform same as those in Ondo. Farmers in Ondo had the highest maximum TE-MF (0.98) while Benue had the lowest (the ideal yam producer with respect to the input level define by the metarfontier was from Ondo). Eliminating the interference of technology and environment on farmer TE, the ideal farmer in Ondo and Enugu would outperform those in Benue. The low mean TE-MFs recorded for Enugu and Ondo could be attributed to a wide distribution of the TE-MF within the States. It is apparent from this analysis that farmers in Enugu and Ondo States performed more than those in Benue State with respect to the technology defined by the metafrontier. There would be improvement in the performance of yam farmers in Enugu and Ondo if farmers could adopt new technologies that are suitable for the States.

The worst farmer in Enugu State in terms of the technology defined by the metafrontier outperformed the less efficient farmer in Ondo States. This implies that on a neutral ground, the worst farmer in Enugu outperformed those in Ondo. It can be inferred from this result that the less performing farmers in Ondo State were able to explore technology/environment to be ahead of those in Enugu. This indicates the need for adoption of new technology for yam production in Enugu. This investigation supports that comparing the technical efficiency of farmers without considering the interference of the environment/technology could give a bias estimate. For instance, the test of hypothesis of full technical efficiency of Nigeria and States, with the efficiency estimates obtained from stochastic frontier estimates, showed that Benue was the only technically efficient State in yam production. The metafrontier analysis revealed that Benue had a favourable environmental conditions and /or technology for yam production in Nigeria. Farmers in Benue were efficient because they could explore technologies and the favourable environmental conditions in the State to attain a high regional technical efficiency. The metafrontier analysis also proved that Enugu State yam farmers outperformed those in others States. The Stochastic frontier analysis shows that Enugu yam farmers are inefficient. This is because Enugu yam farmers are producing in a more restrictive environment and technology. The Stochastic frontier analysis does not account for the environment/technology gap. Therefore, Metafrontier analysis should be employed for technical efficiency studies involving areas with different environment/technologies.

The analysis of the distribution of TE-MF, EMTR and TE-REGION confirms that the technology/environment for yam production in Enugu State is below standard. The distribution of the TE-MF, EMTR and TE-REGIONS in Nigeria is displayed in Figure 2. From the Figure, more farmers in Enugu (71.7%) had EMTR above 0.90. This implies that most of the farmers in Enugu could produce over 90% of their potential output with the technology defined by the metafrontier. Less than half of the population of Ondo and Benue farmers could produce over 90% of their potential output. This suggests that Enugu State yam farmers outperformed those in other States relative to metatechnology (technology defined by the metafrontier). Adoption of new yam technologies suitable for the environmental conditions will improve yam production in Enugu State. This investigation proves that eliminating the influence of the environment and technology on efficiency, yam farmers in Enugu State outperformed those in other States. The result shows that Benue and Ondo States have favourable environments/ technologies for yam production. These States had higher regional TE than Enugu. Most farmers in Benue and Ondo had TE-REGION above 90% while majority of the farmers in Enugu had TE-REGION of between 0.81-0.90. However, Enugu yam farmers are closer to the metafrontier (the State performed more than other States relative to the metatechnology).Yam farmers who had TE-REGION above 90% in Benue and Ondo could explore technologies and the favourable environment available in the States to attain these TE-REGION levels. The Figure also shows that 22.5% of farmers in Enugu had TE-REGION above 90%. This indicates that few farmers in Enugu could attain TE-REGION above 90% given the prevailing technology /environment in the State. Although Enugu State had low regional TE, majority of the farmers produced above 91% of their potential output with the metatechnology. This supports that Enugu farmers are operating in a constrained environment and technology. Nevertheless, some farmers in the State could adopt technology to attain a high TE-REGION. For instance; approximately 37.5% of the farmers in Enugu could produce 81-90% of output on the regional frontier while only 13.3% could produce this level of output with the technology defined by the metafrontier. The farmers who attained this level on the Enugu regional frontier adopted technology or had favourable environment. This signifies a wide variation in the use of technology and environment for yam production in Enugu.

Conclusion

This study has analysed yam production and the efficiency of yam farmers and suggested how these could be improved. It has also detected the existence of environment-technology gap among regions and made recommendations on how it could be closed. The project has established that yam farmers have high efficiency estimates. However, there is still room for farmer performance improvement. The high technical efficiency estimate reported for yam suggests the need to shift the production frontier forward. This could be achieved by adopting improved technologies and mechanization of Nigerian yam farming. The operating environment for yam production differs in Nigeria. Enugu State has a more restrictive environment for yam production in the country. Improvement in the farming conditions of Enugu will boost yam production in the State. Tailoring new technology to suit the environmental conditions and developing an alternative farming system for yam would contribute to improving the performance of yam farmers in Nigeria. Environment-technology gap in yam production exists between regions in Nigeria. Benue and Ondo have favourable environment/technology for yam production in Nigeria. Farmers in Benue are efficient because they could explore technologies and the favourable environment in the State to attain a high regional technical efficiency. The technical efficiency score of yam farmers in Benue could be increased if farmers would maximize the use of inputs. Ondo yam farmers are technically inefficient in yam production because most of the yam farmers in the State are not exploring the available technology/environment. Optimizing the use of input and exploring the suitable conditions for yam production in Ondo will enhance farmer performance. This research stipulates that at the current level of technology and input used for yam production in Nigeria, Ondo would be ahead of yam production in Nigeria if farmers in the State could explore the technologies and optimize the use of resources in the State. This research recommends the intensification of the use of inputs in Ondo and advancement in technology in Benue. This investigation supports that comparing the technical efficiency of farmers without considering the interference of the environment/technology could give a bias estimate. For instance, the test of hypothesis of full technical efficiency of Nigeria and States (with the efficiency estimates obtained from stochastic frontier estimates) showed that Benue was the only technically efficient State in yam production. The metafrontier analysis revealed that Benue had a favourable environmental conditions and /or technology for yam production in Nigeria. Farmers in Benue were efficient because they could explore technologies and the favourable environmental conditions in the State to attain a high regional technical efficiency. The metafrontier analysis also proved that Enugu State yam farmers outperformed those in others States. The Stochastic frontier analysis reported that Enugu yam farmers are inefficient. This is because Enugu yam farmers are producing in a more restrictive environment and technology. The Stochastic frontier analysis does not account for the environment/technology gap. This study has also proved that farm size, quantity of planting material and labour are increasing factors of output in Nigeria. Increased farm size, quantity of planting material, and labour would boost yam output in the country. Farmers in Nigeria should be encouraged to increase their farm size, quantity of planting material and labour. An average Nigerian yam farmer had small farm size. Nigerian land reform policy should aim at redistributing lands to farmers to enable them increase land area under yam production. The findings of this investigation suggest that labour is underutilized in Nigeria, particularly in Ondo State. Labour is expensive relative to farmer income in the country and usually unavailable when required. Therefore, affordable labour-saving devices such as cheap machinery should be used for yam production in Nigeria. Most farmers in Nigeria obtain planting materials for yam production from own farm. Increased use of improved planting materials would boost yam production in Nigeria.

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Table 1: Stochastic frontier (translog) and metafrontier determinants of yam production

Variables	Parameters	Nigeria	Benue	Enugu	Ondo	Metafrontier
Constant term	b_0	0.039**	0.076*	0.12	0.11	-0.042***
		(0.050)	(0.048)	(0.11)	(0.33)	(0.016)
Farm size	b_1	0.49***	0.56***	0.52***	0.11	0.55***
		(0.057)	(0.14)	(0.10)	(0.14)	(0.053)
Planting material	b_2	0.12***	0.090**	0.11**	0.18***	0.15***
		(0.026)	(0.048)	(0.050)	(0.072)	(0.028)
Fertilizer	b_3	0.014	0.034	0.036	0.0045	0.0092
		(0.011)	(0.039)	(0.031)	(0.029)	(0.012)
Labour	b_4	0.25***	0.093	0.23***	0.55***	0.20***
		(0.054)	(0.13)	(0.068)	(0.15)	(0.047)
Capital input	b_5	-0.015	0.047	0.11	-0.035	-0.031
		(0.035)	(0.060)	(0.11)	(0.069)	(0.038)
Farm size^2	b_6	1.16***	0.38	1.01***	3.97*	1.11***
		(0.25)	(2.04)	(0.40)	(2.55)	(0.27)
Planting material^2	b_7	0.19***	0.42***	0.17	-0.010	-0.28***
		(0.080)	(0.14)	(0.17)	(0.55)	(0.091)
Fertilizer^2	b_8	0.0076	0.0077	0.013	0.012	0.0036
		(0.0068)	(0.012)	(0.013)	(0.023)	(0.0041)
Labour^2	b_9	0.14*	-0.83	0.11	6.30***	0.065
		(0.10)	(1.50)	(0.16)	(1.02)	(0.12)
Capital input^2	b_{10}	0.14	0.69 *	-0.16	-0.33	0.12
		(0.18)	(0.47)	(0.66)	(0.31)	(0.20)
Farm size*planting material	b_{11}	-0.39***	-0.79*	-0.31**	0.66	0.42***
		(0.10)	(0.50)	(0.16)	(0.54)	(0.11)
Farm size *fertilizer	b_{12}	-0.0053	0.033	0.0058	0.073	0.0096
		(0.011)	(0.11)	(0.029)	(0.13)	(0.019)
Farm size *labour	b_{13}	-0.63***	0.21	-0.67***	-5.20***	-0.53
		(0.13)	(1.61)	(0.19)	(1.37)	(0.14)
Farm size *capital input	b_{14}	0.052	-1.22**	0.42	0.50	-0.049
		(0.16)	(0.70)	(0.36)	(0.62)	(0.20)
Planting material * fertilizer	b_{15}	-0.0067	0.013	-0.025*	-0.021	-0.0067
		(0.0062)	(0.018)	(0.017)	(0.018)	(0.012)
Planting material * labour	b_{16}	0.20***	0.50	0.23**	-0.68**	-0.20**
		(0.074)	(0.44)	(0.11)	(0.32)	(0.088)
Planting material *capital input	b_{17}	-0.11*	-0.12	-0.44**	-0.14	-0.10
		(0.080)	(0.24)	(0.23)	(0.27)	(0.090)
Fertilizer* labour	b_{18}	0.0027	-0.020	0.0014	-0.089	- 0.0015
		(0.0098)	(0.10)	(0.016)	(0.14)	(0.014)
Fertilizer*capital input	b_{19}	0.017**	-0.031	0.0082	0.023**	-0.0057
		(0.0095)	(0.040)	(0.035)	(0.013)	(0.019)
Labour*capital input	b_{20}	0.0019	1.16**	0.21	-0.30	0.081
		(0.14)	(0.59)	(0.22)	(0.71)	(0. 18)
Diagnostic Statistic	σ^2	0.053***	.026***	0.10***	0.047	
Sigma – squared		(0.0071)	(0.0071)	(0.027)	(0.038)	
Gamma	γ	0.81***	0.78***	0.91***	0.97***	
		(0.066)	(0.16)	(0.10)	(0.28)	
Log likelihood function		152.72***	92.06***	28.54***	80.95***	
LR		15.20***	1.98**	6.80***	6.64***	

Source: Frontier 4.1c and Shazam 11.1 results, 2016

*******, ** and *are significant at 1, 5 and 10% respectively****

Table 2: Stochastic frontier estimates of technical efficiency for yam farmers

Technical efficiency	Nigeria	Benue	Enugu	Ondo
≤0. 50 (%)	0.3	0.00	2.5	0.00
0.51-0.60 (%)	1.1	0.00	5.00	3.3
0.61-0.70 (%)	3.60	0.00	10.8	9.2
0.71 – 0.80 (%)	17.2	1.7	21.7	15
0.81- 9.0 (%)	48.6	35	37.5	34.2
≥0.91 (%)	29.2	63.3	22.5	38.3
Mean technical efficiency	0.86	0.91	0.80	0.85
Maximum technical efficiency	0.97	0.97	0.96	0.99
Minimum technical efficiency	0.49	0.79	0.43	0.56
SD	0.08	0.04	0.12	0.10

Source: Frontier 4.1c, 2015

Table 3: Test of hypothesis of full technical efficiency

Frontier	Hypothesis	LR Test	Degree of freedom	Critical value (5%)	Decision
Nigeria	$H_0 : \gamma = 0$	15.20	1	2.71	Reject H_0
Benue	$H_0 : \gamma = 0$	0.56	1	2.71	Accept H_0
Enugu	$H_0 : \gamma = 0$	6.80	1	2.71	Reject H_0
Ondo	$H_0 : \gamma = 0$	6.64	1	2.71	Reject H_0

Source: Field Survey, 2013

The critical value (X^2) was obtained from (Kodde and Palm, 1986)

Table 4: Test of the null hypothesis that regional frontiers are the same

Log Likelihood Function for States	Log Likelihood Function for Nigeria	Generalized likelihood Ratio Test	Critical Value (5%)	Decision
201.55	152.72	97.66	55.19	Reject null hypothesis

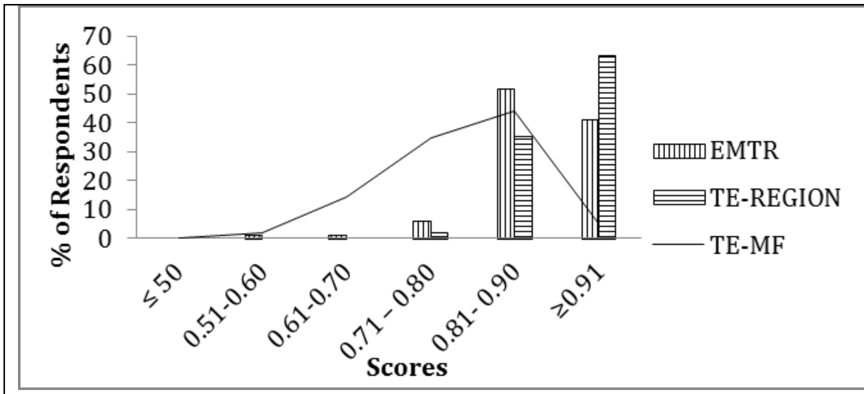
Source: Field Survey, 2013

The critical value (x^2) was obtained from Kodde and Palm, 1986

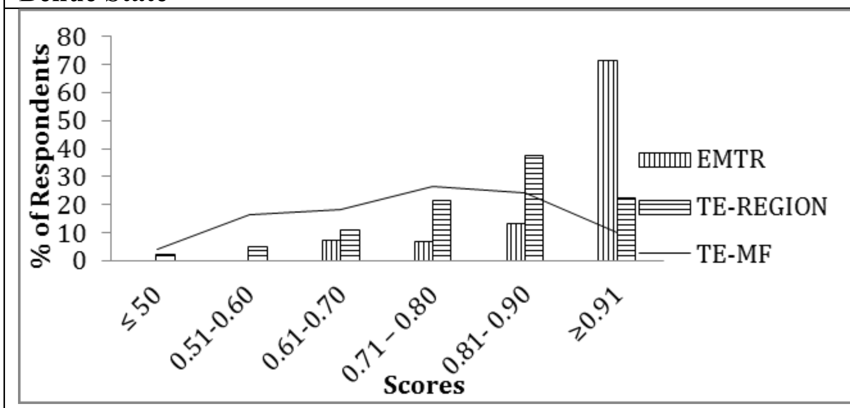
Table 5: Technical efficiency estimates and environment-metatechnology ratio of yam farmers

Regions	Estimates	Mean	Standard Deviation	Minimum	maximum
Benue	TE -REGION	0.91	0.04	0.79	0.97
	TE –POOL (Nigeria)	0.87	0.06	0.71	0.96
	TE- MF	0.80	0.08	0.52	0.94
	EMTR	0.89	0.07	0.58	1.00
Enugu	TE - REGION	0.80	0.12	0.43	0.96
	TE –POOL (Nigeria)	0.83	0.10	0.49	0.96
	TE MF	0.73	0.13	0.43	0.95
	EMTR	0.91	0.10	0.58	1.00
Ondo	TE - REGION	0.85	0.10	0.56	0.99
	TE –POOL (Nigeria)	0.87	0.07	0.66	0.96
	TE MF	0.73	0.13	0.40	0.98
	EMTR	0.86	0.12	0.47	1.00

Source: Frontier 4.1c and Shazam results, 2015



Benue State



Enugu State

Ondo State

Figure 2: Distribution of the TE-MF, EMTR and TE-regions for all States
Source: Frontier 4.1c and Shazam results, 2015