FOOD CROP PRODUCTIVITY IN NIGERIA: AN ESTIMATION OF TECHNICAL EFFICIENCY AND TECHNOLOGICAL GAP RATIO †

[PRODUCTIVIDAD DE CULTIVOS ALIMENTARIOS EN NIGERIA: UNA ESTIMACIÓN DE LA EFICIENCIA TÉCNICA Y LA RELACIÓN DE LA BRECHA TECNOLÓGICA]

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SUMMARY

Background: This study analyzed the determinants of food crop productivity in Nigeria. **Objectives:** To describe the socio-economic characteristics of the food crop farmers, estimate the meta-frontier production and compare the technological gap ratio of the various food crop farmers, and then analyzed the determinants of productivity of food crop farmers in the six geopolitical zones of Nigeria. **Methodology:** General Household Survey –Panel Wave 2 from National Bureau of Statistics Abuja, Nigeria was used for this study, and a total of 1,678 food crop farmers were randomly selected from the six geo-political zones in Nigeria. The study employed the use of descriptive statistics, Data Envelopment Analysis (DEA), and Multiple linear regression. **Results:** Most (34.3%) of the farmers were aged between 41-50 years with modal family size of 6 - 10 members. The illiteracy level was high (62.2%) among the various food crop farmers as they had no formal education. The mean technical efficiency and mean Technological Gap Ratios (TGRs) of the food crop farmers were 0.563 and 0.716 respectively. The difference in the mean technical efficiency and meta-production model of food crop farmers showed a huge productivity potential ratio in the various zones of the country. Age (t = 2.99, P= 0.06), plot size square (t = 4.40, P= 0.00), plot ownership (t =2.59, P= 0.01) and access to credit (t = -2.13, P= 0.033) do significantly influence the productivity of the food crop farmers, and were the determinants of food crop productivity in Nigeria. **Implications:** There is the need to enhance capacity of the food crop enterprises to promote food security and economic growth in Nigeria. **Conclusion:** Given the level of technology available, food crop farmers produce lower than the country potential output.

Keywords: food crop; productivity; meta-frontier; technical efficiency

RESUMEN

Antecedentes: Este estudio analizó los determinantes de la productividad de los cultivos alimentarios en Nigeria. **Objetivos:** Describir las características socioeconómicas de los agricultores de cultivos alimentarios, estimar la producción de la metafrontera y comparar la relación de brecha tecnológica de los diversos agricultores de cultivos alimentarios, y luego analizar los determinantes de la productividad de los agricultores de cultivos alimentarios en el país en seis zonas geopolíticas de Nigeria. **Metodología:** Para este estudio se utilizó la Encuesta General de Hogares - Panel Wave 2 de la Oficina Nacional de Estadísticas de Abuja, Nigeria, y se seleccionó al azar a un total de 1,678 agricultores de cultivos alimentarios de las seis zonas geopolíticas de Nigeria. El estudio empleó el uso de estadística descriptiva, análisis envolvente de datos (DEA) y regresión lineal múltiple. **Resultados:** La mayoría (34.3%) de los agricultores tenían entre 41 y 50 años con un tamaño de familia modal de 6 a 10 miembros. El nivel de analfabetismo fue alto (62.2%) entre los diversos agricultores de cultivos alimentarios, ya que no tenían educación formal. La eficiencia técnica media y las relaciones de brecha tecnológica (TGR) medias de los agricultores de cultivos alimentarios fueron 0.563 y 0.716 respectivamente. La diferencia en el modelo de eficiencia técnica media y metaproducción de los agricultores de cultivos alimentarios mostró una enorme relación potencial de productividad en las distintas zonas del país. Edad (t = 2.99, P = 0.06), cuadrado del tamaño de la parcela (t = 4.40, P = 0.00), propiedad de la parcela (t = 2.59, P = 0.01) y acceso al crédito (t = -2.13, P = 0.033) influyen significativamente en la productividad de los agricultores de cultivos alimentarios y fueron los determinantes de la productividad de los cultivos alimentarios en Nigeria. **Implicaciones:** Existe la necesidad de mejorar la capacidad

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de las empresas de cultivos alimentarios para promover la seguridad alimentaria y el crecimiento económico en Nigeria. **Conclusión:** Dado el nivel de tecnología disponible, los agricultores de cultivos alimentarios producen una producción menor que la del país.
Palabras clave: cultivo alimentario; productividad; metafrontera; eficiencia técnica

INTRODUCTION

In emerging countries like Nigeria, agricultural sector is populated by peasant and resource poor farmers. Most literatures on agricultural productivity growth in Nigeria have reported that over 90% of Nigeria's agricultural output is produced by resource poor farmers, who are the engine behind the national food supply viz-a-viz harnessing of their natural and socio-economic factors of production (Chikezie *et al.*, 2020).

The Nigerian agricultural sector, as part of the real sector of its economy is typified by a multitude of peasant and resource-poor farmers who are scattered over the extensive stretch of land area, in form of small farm holding of about three hectares per farmland, operating rudimentary farming systems, amidst the obvious challenges of low capitalization and low yield per hectare (Ogundari and Ojo, 2007).

The low yields in the farming of arable food crops in Nigeria are the results of the inefficient production techniques, as revealed in technical and allocative inefficiencies, over-reliance on household resources, labor-intensive agricultural technology and rapidly declining soil productivity. And it is only when there is a boost in the farm-level efficiency of resource use in arable crop production, that there will be an improvement in the welfare of the rural farming households as well as a reduction in their poverty level and food insecurity status (Anang *et al.*, 2020; Eze *et al*., 2010). The prevalence of food insecurity and poverty statuses of the majority of the rural farming households (which have been shown to have a negative and significant effect on technical efficiency (TE) in resource utilization), poor nutrition (which results from the problem of food insecurity and low-income statuses of rural farming households) has dampened labour productivity within the rural farming households as well as weaken their access to productive farm inputs and household resources (Dare, 2008). Based on the aforementioned problems, this study describe the socio-economic characteristics of the food crop farmers in the study area; analyze the technical efficiency of the food crop farmers in the study area; estimate the meta-frontier production and compare the technological gap ratio of the various food crop farmers in the study area; and analyze the determinants of productivity of the food crop farmers in the study area. The hypothesis of this study as stated in the null forms was: there is no significant difference in the meta-frontier technical efficiency of the food crop farms in the study area.

The increase of agricultural productivity growth can depend on either of the following: a raise in output and input, with output increasing proportionately more than inputs; an increase in output while inputs remain constant; a decrease in both output and input, with input decreasing more; or decreasing input while output remains constant (Oni *et al.,* 2009). Empirical analyses with alternative stochastic frontier models are evidently desirable, even Mariko *et al.,* (2019) and Feng *et al.,* (2018) used this method to examine the technological gap and technical efficiencies of firms in the garment industry in different regions of Indonesia. One of the new extensions of the model is meta-frontier model. DEA is a linear-programming method that uses data on input and output quantities of a Decision Making Units (DMU) such as individual firms of a specific sector. The DEA method is closely related to the approach of Farrell (1957) and it is widely regarded in the literature as an extension of that approach. Charnes *et al.,* (1978) were the initiator of the approach. DEA is nonparametric in nature and it applies mathematical programming to measure efficiency, and not imposing any limitation on the data set. It is employed to construct different production frontiers as well as meta-frontier.

Linear combination of several firms with different technologies can be a segment of the meta-frontier. DEA can be either input-orientated or output-orientated (Olarinde *et al.,* 2020; Anang *et al.,* 2020). In the input-orientated case, DEA defines the frontier by looking for the maximum possible proportional reduction in input usage, with output levels held constant, for each unit. In the output-orientated case, the DEA method seeks the maximum possible proportional increase in outputs, with input levels held fixed. The two measures afford the same technical efficiency scores when a constant returns-to-scale (CRS) technology applies, but are unequal when variable returns-to-scale (VRS) technology holds. Given that units are within regions it is possible to identify a "regional frontier" using DEA on the data for units from the given region. Thus, DEA can be used to construct K regional frontiers. The meta-frontier is then constructed by using DEA to analyze the data set obtained by pooling all the observations for units from all the regions. The Cobb Douglas and trans-log models tremendously dominate the applications literature in stochastic

frontier and econometric inefficiency estimation (Greene, 2003).

In the estimation of the technological gap and efficiency levels, the observed output for the ith state in the jth zone can be expressed by $Y_i = e^{x_i\beta + v_i} or Y_i = e^{x_i\beta* - v_{i*}}$ from which it follows that the relationship $x_i\beta + v_i - u_i = x_i\beta^* + v_{i^*} - u_{i^*}$ is satisfied. It is expected that the deterministic values xiβ and xiβ* satisfy the inequality xiβ ≤ xiβ* because xiβ* is from the meta-frontier. If the meta-frontier were estimated to be an envelope function for efficient states, then the relationship would be satisfied by the estimated functions. The relationship can then be rewritten as:

$$1 = \frac{x_i\beta}{x_i\beta^*} \cdot \frac{e^{Vi}}{e^{Vi*}} \cdot \frac{e^{-Ui}}{e^{-Ui*}} \ldots \quad (1)$$

The three ratios at the right -hand side of the equation are called the Technological Gap Ratio (TGR), Random Error Ratio (RER), and the Technical Efficiency Ratio (TER), that is:

$$TGR \equiv \frac{e^{xi\beta}}{e^{xi\beta*}} \equiv e^{-xi(\beta*-\beta)}, \ldots \quad (2)$$

$$RER \equiv \frac{e^{Vi}}{e^{Vi*}} \equiv e^{Vi} - e^{Vi*} \ldots \quad (3)$$

$$TER \equiv \frac{e^{-Ui}}{e^{-Ui*}} \equiv \frac{TE_i}{TE_{i^*}} \ldots \quad (4)$$

The technological gap ratio indicates the technology gap for the given group according to currently available technology for the states in that zone, relative to the available technology of the whole country. However, only two of these ratios are needed to be independently estimated in any empirical application.

METHODOLOGY

The study area was Nigeria which comprise of 36 states and the federal capital territory (Abuja). Secondary data were used for this study. Nigeria General Household Survey (GHS) –Panel Wave 2 (2012/2013) Post Harvest Data from National Bureau of Statistics Abuja, Nigeria was used for the study. GHS is a survey of over 30,000 households carried out annually in the whole country. A quantitative questionnaire was undertaken, so as to collect information on labour force, employment, unemployment and underemployment. Also, information on demographic and socio-economic characteristics of the population was extracted. A total number of 1,678 respondents were randomly selected from the six geo-political zones in Nigeria. North Central Zone - 427; North East Zone - 463; North West Zone - 33; South East Zone - 443; South-South Zone - 232; and South West Zone - 80.The reason for the wide disparity in the sample sizes was due to a lot of missing data. The methods of data analysis employed in this study include Descriptive Statistics, Data Envelopment Analysis (DEA) Approach to Meta-frontier and multiple regression analysis.

Technical Efficiency in Data envelopment analysis

Technical efficiency (TE) is estimated by either input-oriented or output-oriented analysis (Martey *et al.*, 2015; Ray 2015 and Kumbhakar *et al.*, 2015). So, the estimation is approached with the use of either parametric or non-parametric methods. The choice of either of the two approaches relies on either input minimization and/or output maximization when all other elements are held constant. In this study, we choose non-parametric approach to estimate the efficiency score.

The Data envelopment analysis (DEA) attempts to benchmark the performance of each unit against the best practice for all units. The “best-practice” is derived after taking into account the output structure (e.g share of crops and livestock in total output) as well as the input structure of the unit under consideration. A measure of technical efficiency is then obtained by measuring the radial distance of the unit from its best practice. The technique also identifies the units in the data set that define the best practice – such units are referred to as “peers”. The measure the importance of each of the peers through a set of weights derived through the application of the DEA technique. The efficiency of farms in different zones that may not have same technology may be investigated as Battese and Rao (2002) suggested. This enables one to estimate the agricultural productivity of a place in which their technological gap is relative to their meta-production frontier. Since there are states in the zones, the zonal frontier can be estimated. Then, the meta- frontier is estimated using DEA by pooling all the data set of the states in the zones which make up Nigeria. The duality envelopment form is given in equation 5:

$$\begin{aligned} &\text{Max}\theta,\lambda\theta, \\ &\text{Subject to} \quad -yi + Y\lambda \geq 0 \\ &\theta xi - X\lambda \geq 0 \\ &\lambda \geq 0 \ldots (5) \end{aligned}$$

Where θ a scalar and λ is an Nx1vector of constants. θ takes a value greater than or equal to one, and it measures the ratio of observed vector of output to the highest vector that can be achieved when given the

input vector. The value of θ obtained is the efficiency of the ith state. The constant returns to scale (CRS) assumption are appropriate only when all the farms are performing at an optimal level while, the variable returns to scale will allow the calculation of efficiency scores devoid of scale efficiency effects. According to Coelli (1996), the VRS specification has being the most commonly used specification in the 1990's; this would be opted for in this thesis. The linear programming problem under constant returns to scale (CRS) to variable returns to scale (VRS) is given as,

Maxθ,λθ,
Subject to -yi + Yλ ≥ 0
θxi - Xλ ≥ 0
N1'λ ≥0
λ ≥ 0…………………………………………… (6)

Where N1 is an Nx1 vector of one. Assuming there are data on N state in a given zone P, the above linear program will be solved N times. The meta-frontier is constructed using DEA model based on the pooled data of all states in zones. We ran the above linear program model with output and inputs matrices with the data from all the states.

The functional form chosen for the determinants of productivity for all the farmers in the six geo-political zones of Nigeria is the Ordinary Least Square Regression (OLS) form for the *ith* farmer is defined by:

$$Y_i = \beta_0 + \sum_{m=1}^{4} \beta_m x_{mi} + \sum_{m=1}^{4} \sum_{k\geq m}^{4} \beta_{mk} x_{mi} x_{ki} + v_i + u_i \quad (7)$$

i and m indices represent the input *m* used by farmer *i*. This was used to estimate the relationship between the agricultural crop output (dependent variable) and inputs (independent variables):

The efficiency scores, which reveal the managerial capacity of the farmers to transform available production inputs into maximum feasible output with or without increasing the input-base at a particular state of technology were derived using DEA (Non-parametric) Analysis. These efficiency scores revealed food crop farmers' performances in their food crop farming enterprise. Hence, to determine the factors influencing the productivity of the food crop farmers, their efficiency scores were run against their socio-economic characteristics.

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \cdots + \beta_{10} x_{10} + u_i \quad (8)$$

Where

Y =Efficiency scores;X_1 = Age of the farmers (in years); X_2 = Household size (in numbers)
X_3 = Household size^2 (in numbers); X_4 = Gender (dummy), X_5 = Marital status (dummy); X_6= Years of education (in years), X_7 = Plot size (in hectares); X_8 = Plot size^2(in hectares); X_9 = Access to credit (dummy), X_{10} = Plot owned(dummy); β0 =Constant; β1= Parameters to be estimated, U = error term, assume to have a zero mean and constant variance

RESULTS

Table1 shows the distribution of respondents by their age, sex, marital status, household size and educational status. The mean ages of the of the food crop farming population in all the six zones were 50.5 (NC), 52.4 (NE), 50.9 (NW), 49.9 (SE), 49.7 (SS), and 50.5 (SW) years respectively. The food crop enterprises in all the six geo-political zones of Nigeria were dominated by male farmers (88.4%) of the total population About 89% of the food crop farmers in six geo-political zones were married (either as Monogamist and Polygamist) and 9.9% of them were widowed. By implications, the food crop production enterprises in all six geo-political zones of Nigeria are dominated by married people. The mean household sizes for the North-Central was 6.9, North-East has 7.9, North-West has 6.6, South-East has 6.2, South-South has 6.1 and South-West has 5.8. Household size is in medium range in all the six geo-political zones of Nigeria. About 62% of the food crop farming population had no formal education while 16.4% of the food crop farmers from all the six zones had tertiary education. On the average, there exists a very low literacy level among the various food crop farmers in all the six geo-political zones of Nigeria. The result further shows that 84.4% of the food crop farming population had about 5 hectares of farmland while those that have about 6-10 hectares of land were 15.4%. From the table, 26.3% of the food crop farmers in the North central and 30.7% from the South East zones acquired their land from lease tenure system, 26.5% of the food crop farmers in North East and 36.4% North West zones acquired theirs by renting, 42.2% in the South-South zones got their own land through gift, and 25.9% of the food crop farmers in South-West zone, purchase their farm land.

Technical efficiency and technological gap ratio

The average zonal DEA technical efficiency, the meta-production frontiers and the technological gap ratios (TGRs) are presented in Table 2. The mean technical efficiencies for the six geopolitical zones (aggregated) ranged from 0.063 to 1.000 with an average of 0.403. The mean technical efficiency of North-Central was 0.512, North-East has

Table 1a. Distribution of respondents by their socio-economic characteristics.

Variable	North Central		North East		North West		South East		South South		South West		Pooled	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Age														
≤30	16	3.8	5	1.0	1	3.0	21	4.7	14	6.1	2	2.5	59	3.5
31-40	43	10.1	67	14.5	6	18.2	19	20.5	56	24.1	9	11.3	272	16.2
41-50	162	37.9	162	34.6	9	27.3	134	30.3	75	32.3	35	14.8	575	34.3
51-60	150	35.1	127	27.4	11	33.3	94	21.2	46	19.8	21	26.2	449	26.8
Above 60	56	13.1	104	22.5	6	18.2	103	32.3	41	17.7	13	16.2	323	19.2
Mean	50.5		52.4		50.9		49.9		47.9		49.7		50.5	
Total	427	100	463	100	33	100	443	100	232	100	80	100	1678	100
Sex														
Female	40	9.4	92	19.9	2	6.1	31	7.0	22	9.5	8	10.0	195	11.6
Male	387	90.6	371	80.1	31	93.9	412	93.0	210	90.5	72	90.0	1483	88.4
Total	427	100	463	100	33	100	443	100	232	100	80	100	1678	100
Marital Status														
Married (Mono)	166	38.9	300	64.8	20	60.6	279	62.8	140	60.3	43	53.8	948	56.5
Married (Poly)	212	49.7	89	19.2	13	39.4	124	27.9	72	31.0	32	40.0	542	32.3
Never married	4	0.9	2	0.4	-	-	1	0.23	2	0.9	1	1.3	10	0.6
Separated	1	0.2	4	0.9	-		4	0.90	1	0.4	1	1.2	11	0.7
Widow	44	10.3	68	14.7	-	-	35	7.90	17	0.4	3	3.7	162	9.9
Total	427	100	463	100	33	100	443	100	232	100	80	100	1678	100
Household Size														
≤5	133	31.2	120	25.9	14	42.4	170	38.4	96	41.4	41	51.3	574	34.2
6-10	243	56.9	232	50.1	12	36.4	258	58.2	122	52.6	33	41.2	900	53.6
Above10	51	11.9	111	23.1	7	21.2	15	3.4	14	6.0	6	7.5	204	12.2
Mean	6.9		7.9		6.6		6.2		6.1		5.8		6.9	
Total	427	100	463	100	33	100	443	100	232	100	80	100	1678	100
Educational Status														
Primary Education	43	10.1	22	4.8	13	9.0	14	3.2	6	2.6	4	5.0	92	50.5
Secondary Education	55	12.8	43	9.3	9	27.3	53	11.9	14	6.0	9	11.2	183	10.9
Tertiary Education	63	14.8	55	12.8	3	9.1	105	23.7	32	13.8	17	21.2	275	16.4
Vocational & other	36	8.4	12	2.6	-		7	1.6	18	7.8	5	6.3	78	4.6
None	230	53.9	331	71.5	18	54.6	264	59.6	162	69.8	45	56.3	1050	62.6
Total	427	100	463	100	33	100	443	100	232	100	80	100	1678	100

Table 1b. Distribution of respondents by their socio-economic characteristics (cont'd).

Variable	North Central		North East		North West		South East		South South		South West		Pooled	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Farm Size														
≤5	289	67.7	356	76.9	15	45.5	443	100	232	100	80	100	1,415	84.4
6-10	135	32.3	104	22.5	17	51.5	-	-	-	-	-	-	259	15.4
Above10	-	-	3	0.6	1	3.0	-	-	-	-	-	-	4	0.2
Mean	4.5		4.2		5.6		0.6		0.5		0.9		2.7	
Total	427	100	463	100	33	100	443	100	232	100	80	100	1678	100
Type of Land Tenure														
Inheritance &Lease	77	17.1	45	9.9	7	21.2	66	12.9	8	3.5	6	7.8	205	12.4
Inheritance	35	8.2	49	10.7	1	3.0	31	7.0	29	13.0	8	10.4	153	9.2
Communal land	35	8.2	118	25.8	8	24.2	57	4.9	34	11.3	12	15.6	264	12.9
Lease	112	26.3	43	9.4	3	9.1	136	30.7	27	12.1	14	18.2	335	20.2
Gift	88	20.7	54	11.8	2	6.1	61	13.8	94	42.2	12	19.5	314	18.9
Purchase	42	9.9	27	5.9	-	-	49	11.0	12	5.4	20	25.9	150	9.0
Rented	41	9.6	121	26.5	12	36.4	43	9.7	19	8.5	2	2.6	238	14.4
Total	426	100	457	100	33	100	443	100	223	100	77	100	1659	100
Source of Start-up Capital														
Esusu/Adashi up capital	9	2.11	7	1.5	-	-	13	2.9	-	-	-	-	29	1.7
Household savings	220	51.5	164	35.4	7	21.2	286	64.5	48	20.7	32	41.0	757	45.2
Money Lender	112	26.2	4	0.9	-	-	4	0.9	-	-	-	-	8	0.5
No Response	67	15.7	209	45.1	19	57.6	77	17.4	148	61.7	21	26.7	566	34.9
Family non-enterprise	19	4.5	19	4.1	-	-	8	1.8	5	2.2	2	2.5	34	2.6
Proceed from Family farm	-		30	5.5	4	12.1	41	9.3	12	5.2	25	31.2	179	10.7
NGO	-	-	-	-	-	-	7	1.6	-	-	-	-	7	0.4
Relatives/ friends	-		4	5.6	3	9.3	4	0.9	19	8.2	-	-	71	4.2
Total	427	100	463	100	33	100	443	100	232	100	80	100	1678	100
Source of Info														
Electronic Media	138	32.3	74	16.0	9	27.3	95	21.4	67	28.9	22	27.5	405	24.1
Extension Services	289	67.7	331	71.5	24	72.7	221	49.9	160	68.9	57	71.3	1082	64.5
NGO	-		1	0.2	-		43	9.8	-		1	1.2	45	2.7
Neighbour/Relative	-		42	9.1	-		52	11.7	2	0.7	-		50	5.7
Private Ext.	-		15	3.2	-		32	7.2	3	1.3	-		50	3.0
Total	427	100.0	463	100.0	33	100.0	443	100.0	232	100.0	80	100.0	1678	100.0

0.473, North-West has 0.439, South-East 0.565, South-South 0.644, and South-West 0.745. The interesting feature is the difference between the average technical efficiency scores from the zones and meta-frontier models. The average technical efficiency for the South Western zone relative to the meta-frontier was only 0.546 while its mean efficiency is quite large with respect to its own zonal frontier 0.745, having a difference of 0.199. Of all the six geo-political regions of Nigeria, the South-West zone's food crop production enterprise had the highest mean technical efficiency relative to its meta-frontier production technology (0.546) and zonal frontier (0.745) as compared to other zones. North Central zone had the least efficiency (0.269) with respect to meta-frontier but a higher zonal frontier (0.512) compared to North East (0.473) and North West (0.457). Estimates for technological gap ratios of the six (6) zones of the country have productivity potential ratio ranging between 0.525 and 0.961. The North Central zone had the least productivity potential (0.525). The North-West, South-East and South-South zones of Nigeria had higher productivity potentials of 0.961, 0.874 and 0.821 respectively The North-East and South-West zones had TGR of 0.734 and 0.733 respectively. It could be seen that the TGR for the North-East, North-West, South-East, South-South and South-West zones are higher than the TGR of the six geopolitical zones, Nigeria as a whole (pooled).

Determinants of the productivity of the food crop farm in the six geopolitical zones of Nigeria.

The result of multiple regression analysis on the determinants of food crop productivity in the North Central zone of Nigeria is presented in Table 3. The adjusted R^2 (coefficient of determination) of 0.529 shows that 52.9% of the variations in productivity were explained by the joint effect of all the explanatory variables included in the model. Household size was positively related to productivity of various food crop farm owners at 10% level of significance. Plot size also was positively related to productivity of the food crop farmers at 10% level of significance, this suggests higher and better levels of productivity and outputs are expected from food crop farmers having larger plot sizes. Plot ownership had an inverse relationship (negative) with the productivity of the food crop farmers at 5% level of significance, it indicates that the nature of the tenure system in any region, which determines the rights to

Table 2. Technical Efficiency and Technological Gap Ratio.

Zone					Mean	Min	Max	Std. Dev
North Central	TE	DEA	NC	REG	0.512	0.063	1.000	0.163
		DEA	NC	MF	0.269	0.103	1.000	0.285
	TGR	DEA	NC	TGR	**0.525**			
North East	TE	DEA	NE	REG	0.473	0.084	1.000	0.272
		DEA	NE	MF	0.347	0.067	1.000	0.236
	TGR	DEA	NE	TGR	**0.734**			
North West	TE	DEA	NW	REG	0.457	0.013	1.000	0.349
		DEA	NW	MF	0.439	0.154	1.000	0.241
	TGR	DEA	NW	TGR	**0.961**			
South East	TE	DEA	SE	REG	0.565	0.079	1.000	0.286
		DEA	SE	MF	0.494	0.009	1.000	0.291
	TGR	DEA	SE	TGR	**0.874**			
South South	TE	DEA	SS	REG	0.644	0.108	1.000	0.284
		DEA	SS	MF	0.529	0.108	1.000	0.293
	TGR	DEA	SS	TGR	**0.821**			
South West	TE	DEA	SW	REG	0.745	0.249	1.000	0.252
		DEA	SW	MF	0.546	0.172	1.000	0.282
	TGR	DEA	SW	TGR	**0.733**			
POOLED	TE	DEA	NIG	REG	0.563			
		DEA	NIG	MF	0.403			
	TGR	DEA	NIG	TGR	**0.716**			

Table 3a. Determinants of the productivity of food crop farmers in Nigeria.

Variable	North Central Coefficient	Standard error	P-Value	North East Coefficient	Standard error	P-Value	North West Coefficient	Standard error	P-Value
Age	0.001	0.001	0.492	-0.000***	0.000	0.005	-0.007*	0.004	0.066
Household size	0.015*	0.009	0.082	0.004	0.077	0.617	-0.039	0.077	0.619
Household size square	-0.001	0.001	0.323	-0.000	0.000	0.598	0.001	0.005	0.844
Gender	0.031	0.040	0.436	0.035	0.043	0.421	0.047	0.179	0.794
Marital status	-0.059	0.037	0.113	-0.014	0.047	0.762	0.051	0.121	0.676
Years of education	0.001	0.001	0.308	0.001	0.002	0.453	0.008	0.008	0.367
Plot size	0.001*	0.000	0.072	0.002***	0.000	0.001	0.070	0.076	0.365
Plot size square	0.001	0.002	0.548	-0.000	0.000	0.824	-0.003	0.005	0.543
Access to credit	-0.002	0.025	0.946	-0.088	0.082	0.284	0.607***	0.206	0.007
Plot Own	-0.052**	0.022	0.019	0.067	0.081	0.410	-0.623***	0.219	0.009
Constant	0.287	0.073	0.000	0.291	0.077	0.000	0.630	0.422	0.149
R-square	0.552			0.412			0.486		
Adjusted R-square	0.529			0.409			0.467		
F-value	2.27			0.55			1.38		

Table 3b. Determinants of the productivity of food crop farmers in Nigeria (cont'd).

Variable	South East			South South			South West			Nigeria		
	Coefficient	Standard error	P-Value	Coefficient	Standard error	P-Value	Coefficient	Standard error	P-Value	Coefficient	Standard error	P-Value
Age	0.000	0.001	0.814	0.000	0.001	0.638	-0.005	0.003	0.134	0.006***	0.002	0.003
Household size	-0.029	0.026	0.255	-0.037	0.027	0.168	0.861**	0.409	0.035	-0.000	0.000	0.661
Household size^2	0.003	0.002	0.185	0.002	0.002	0.283	0.002	0.004	0.595	-0.000	0.029	0.498
Gender	0.006**	0.002	0.022	0.009	0.093	0.915	- 0.083	0.121	0.498	0.019	0.003	0.900
Marital status	-0.005	0.089	0.559	0.009	0.099	0.925	-0.009	0.146	0.562	-0.004	0.000	0.305
Years of education	0.002	0.002	0.333	0.465**	0.211	0.028	0.007	0.005	0.146	0.000	0.004	0.000
Plot size	0.013	0.059	0.823	-0.022*	0.013	0.088	-0.003**	0.122	0.022	0.001	0.002	0.055
Plot size^2	0.004	0.017	0.802	-0.029	0.023	0.210	0.078**	0.038	0.044	0.001***	0.022	0.033
Access to credit	0.162***	0.539	0.003	0.031	0.054	0.569	-0.045	0.076	0.560	-0.046**	0.021	0.010
Plot Own	0.096	0.093	0.304	0.009	0.052	0.848	0.069	0.082	0.402	0.055***	0.042	0.000
Constant	0.489	0.116	0.000	0.580	0.149	0.000	1.171	0.252	0.000	0.482		
R-square	0.529			0.634			0.481			0.500		
Adjusted R^2	0.518			0.620			0.462			0.495		
F-value	1.79			0.54			1.52			18.58		

own, and use the land will always impact negatively on the productivity of food crop farmers, due to certain inherent constraint associated with such tenure system. The adjusted R^2 (coefficient of determination) of 0.409 shows that 40.9% of the variations in productivity were explained by the joint action of the explanatory variables included in the model in the North East zone of Nigeria. From the result, the two explanatory variables that were significant are age and plot size. Age had an inverse relationship (negative) which was significant at 1% level of significance with the productivity of the food crop farmers in the zone. The plot size had a positively relationship which was significant at 1% level of significance with the productivity of the food crop farmers in the zone. In the North West zone of Nigeria, the adjusted R^2 (coefficient of determination) of 0.467 implies that 46.7% of the variations in productivity were explained by the joint action of the explanatory variables included in the model. Age had an inverse relationship (negative) which was significant at 10% level of significance with the productivity of the food crop farmers in the zone. This result however agreed with Obasi *et al*., (2013) which found that age has a negative influence on productivity. Access to credit had a positive relationship which was significant at 1% level of significance with the productivity of the food crop farmers in the zone. Beyene (2020) showed that access to credit contributed negatively towards inefficiency among farmers, implying that it improved technical efficiency of farmers. Plot owned also had an inverse relationship (negative) which was significant at 1% level of significance with the productivity of the food crop farmers in the zone. This implies that the nature of the tenure system in any region, which determines the rights to own, and use the land will always impart negatively on the productivity of food crop farmers, due to certain inherent constraint associated with such tenure system. This is incongruent with the findings of Amusa *et al.,* (2011) where plot owned is positive and significant. In Table 3, the result of multiple regression analysis on the determinants of food crop productivity in the South East zone of Nigeria presented the adjusted R^2 (coefficient of determination) of 0.518 showing that 51.8% of the variations in productivity were explained by the joint action of the explanatory variables included in the model. From the result, gender and access to credit were the only two independent variables that were significant and both had a direct (positive) relationship which was significant at 5% and 1% levels of significance respectively with the productivity of the food crop farmers in the zone. Access to credit has being established as a vital factor powering productivity. The result of multiple regression analysis on the determinants of food crop productivity in the South-South zone of Nigeria shows that the adjusted R^2 (coefficient of determination) of 0.620 indicate that 62.0% of the variations in productivity were explained by the joint action of the explanatory variables included in the model. From the result, years of education and plot size were the only two independent variables were significant at 5% and 10% levels of significance respectively with the productivity of the food crop farmers in the zone. The years of education had a direct (positive) relationship with productivity of the food crop farmers in the study area. This conforms to the findings of Idjesa (2007) who found out that education was key to enhanced productivity among farming households in the humid forest, dry savannah and moist savannah agro-ecological zones of Nigeria. The plot size had an inverse (negative) relationship with the productivity of the food crop farmers in the study area. The result of multiple regression analysis on the determinants of food crop productivity in the South-West zone of Nigeria presented adjusted R^2 (coefficient of determination) of 0.462 that signify that 46.2% of the variations in productivity were explained by the joint action of the explanatory variables included in the model. Household size had a positive relationship which was significant at 5% level of significance with the productivity of the food crop farmers in the zone. The plot size square had a positive relationship which was significant at 5% level of significance with the productivity of the food crop farmers in the zone. This result was incongruent with the result from Oni *et al.* (2009) where there is an inverse relationship between farm area and crop productivity.

From the Table 3, the result of the determinants of the productivity of the food crop farmers in the six zones of Nigeria (pooled) reveal the adjusted R^2 (coefficient of determination) of 0.495 showing that 49.5% of the explained variation in the productivity of the food crop farmers in the six geopolitical zones of Nigeria was captured by the joint effect of all the independent variables included in the model, while the rest 50.5% of the unexplained variation in their productivity may be due to other variables of interest not specified in the model, but which are present in the error term. The value of adjusted R^2 (coefficient of determination) and the significance of F-ratio at 10% level confirmed the goodness of fit of the model. From the pooled result, only four independent variables were significant at different levels. These include: age, plot size square, plot ownership and access to credit. The estimated coefficients of age, plot size square and plot ownership was significant at

1% level of significance and had a direct (positive) relationship with the productivity of the food crop farmers. This implies that, as the food crop farmers advance in age, their productivity profile improves and this may be due to better managerial and farm-level supervisory skills developed by their years of farming experience and access to agricultural extension innovation practices and workshops. This result, however, negated the findings of Mitra and Yunus (2018) who reported efficiency decreases with age. Also, as the plot size square increases, the productivity of the food crop farmers also increases. Plot ownership was positive and significant at 1% level of significance. The elasticity of production suggests that if the plot own by the farmers on which is cultivable is increased by 10%, productivity will be increased by 1.39%. The rate of control over land for agricultural production according to FAO (2005) is a major factor affecting farmers to decide if they should expand or invest on their farm land, which have been revealed by many authors to have positive relationship with productivity (Fabiyi *et al.*, 2007). This finding is congruent with the findings of Amusa *et al.,* (2011) that plot ownership has a direct and significant relationship with productivity of farmers. Access to credit was negative and significant at 5% level of significance.

Investigating the difference in the meta-frontier technical efficiencies of the food crop farmers in the six zones

The results of two-sample t-test with equal variances carried out on the pairing of the food crop farmers' meta-frontier technical efficiencies in all of the six zones, as shown in Table 4 reveals the following findings: For the pairings of North-East and North-West, North-East and North-Central, North-East and South-East, North-East and South-South, North-East and South-West, North-Central and North-West, North-Central and South-East, North-Central and South-South, and North-Central and South-West zones of Nigeria, the null hypothesis which states that there is no significant difference in the meta-frontier technical efficiencies of food crop farmers in the paired zones was rejected. Hence, there exists a negative difference in the meta-frontier technical efficiencies of the food crop farmers in each of the above paired zones of Nigeria which was significant at 1% (with t-values for each paired as -2.584, -5.654, -8.374, -8.811, -6.744, -6.117, -13.986, -14.603, and -12.137 respectively). For each of the above paired zones there exists a wide disparity in the sample sizes available for analysis after rigorous data cleaning. This could also be responsible for the negativity of the significant difference of their meta-frontier technical efficiencies of food crop farmers in the paired zones. More so, for the pairings of North-West and South-East, North-West and South-South, North-West and South-West, South-South and South-East, South-East and South-West and South-South and South-West zones, the null hypothesis which states that there is no significant difference in the meta-frontier technical efficiencies of food crop farmers in the paired zones was accepted. Hence, the meta-frontier technical efficiencies of the food crop farmers in each of the above paired zones of Nigeria are not significantly different from each other.

DISCUSSION

Rural farmers produce the largest percentage of food crops in Nigeria. Most of these farmers are majorly in the category of non-productive age. That is, more than 60 years; the average age of the food crop farmers in this study corroborated Mumba 2018. The result implied that most of the young adults were not involved actively in food crop enterprises in all the zones. This could be a result of rural-urban migration which is prevalent in the country. Most of the farmers were male and few were female; this result was in congruent with the findings of Balogun and Akinyemi (2017). Allocation of productive assets has been a major problem depriving female farmers. Most of the female farmers do not have access to production assets such as land, credit. This have for long serves as an impediment for women in agriculture. However, there is the need to encourage and empower more female farmers to engage in food crop production enterprises in all the six geo-political zones of Nigeria.

Labour is very essential to food crop production. Food crop production is labour demanding in this part of the world where subsistence farming was prominent. The use of household members for farming activities have been reported by research authors (Olumba 2014 and Danso-Abbeam and Baiyegunhi 2020) despite the fact that most household are not extensively large. This study showed that family labour is widely used across the six geo-political zones in Nigeria which will eventually have effect on the number of hired labour employed for farming activity. Furthermore, the types of land tenure system adopted by farmers in any region or zone determine to what use they can put the land under their care to, the rights and ownership status to be maintained. By implications, food crop farmers in all the zones are operating on scattered and fragmented farmlands, which is a disincentive to large-scale food crop production in Nigeria.

Table 4. T- test for investigating the difference in the meta-frontier technical efficiencies of the food crop farmers in the study area.

Group	Mean	Standard error	t- value	Pr(T<t)	Decision
NE & NW	0.354	0.011	-2.584*	0.005	Reject H_0
NE & NC	0.309	0.007	-5.654*	0.000	Reject H_0
NE & SE	0.419	0.009	-8.374*	0.000	Reject H_0
NE & SS	0.408	0.010	-8.811*	0.000	Reject H_0
NE & SW	0.376	0.109	-6.744*	0.000	Reject H_0
NW & SE	0.491	0.013	-0.712	0.238	Accept H_0
NW & SS	0.529	0.018	-1.342	0.090	Accept H_0
NW & SW	0.519	0.026	-1.583	0.058	Accept H_0
NC & NW	0.282	0.008	-6.117*	0.000	Reject H_0
NC & SE	0.384	0.009	-13.986*	0.000	Reject H_0
NC & SS	0.361	0.009	-14.603*	0.000	Reject H_0
NC & SW	0.313	0.009	-12.137*	0.000	Reject H_0
SS & SE	0.506	0.011	-1.469	0.071	Accept H_0
S E & SW	0.502	0.013	-1.471	0.071	Accept H_0
SS & SW	0.533	0.016	-0.453	0.326	Accept H_0

*represent level of significance at 1 %

Note: NE – North east; **NC –** North central; **NW –** North west; **SE –** South east; **SS –** South-South; **SW –** South west.

The TE indicating that the food crop farmers from the entire geo-political zones of Nigeria are only able to produce 40.3% of the country's potential output at the given level of technology and this presents a huge potential for agricultural productivity improvements (i.e. about 59.7% unattained potential output level) in its agricultural food crop sub-sector. The estimate was in line with findings of Mekonnen *et al.,* (2015); Olarinde *et al.,* (2020) and Hakim et al., (2021); these authors showed that the TE was very low in their study area. The average technical efficiency for the South Western zone relative to the meta-frontier was only 0.546 while its mean efficiency is quite large with respect to its own zonal frontier 0.745, having a difference of 0.199. By implication, the difference between the two efficiency scores indicates the order of bias of the technical efficiencies obtained by using zonal frontiers relative to the technology available for the agricultural sector in Nigeria. The zonal frontier is greater than the meta-frontier because the constraints in the zonal linear programming problem are a subset of the constraints in the meta-frontier linear programming problem. Therefore, there is the need for the other five geo-political zones of Nigeria to benchmark the technology employed in the zone to better improve their productivity levels. In general, zones in the Southern part of the country have higher efficiencies in meta-frontier and zonal frontier compared to those in Northern part of Nigeria and the result was in line with Ogundari (2009) findings where South-West zone have the highest (0.842) efficiencies relative to meta-frontier.

Estimates for technological gap ratios of the six (6) zones of the country have productivity potential ratio ranging between 0.525 and 0.961. These values can be interpreted as the technological gap faced by the agricultural sector in those geopolitical zones when their performances are compared with the national level (pooled). The North Central zone had the least productivity potential which shows that they have high technological gap. Implying that their technology could be old or the farmers lack technical know-how of their technologies and or have reached high level of efficient use. Therefore, they have to move to the best frontier if they must improve on their productivity.

Also, the North-West, South-East and South-South zones of Nigeria had higher productivity potentials which implied that they have low technological gap with North West having the least gap. By implication, they have to look for new technologies because the ones they are using presently may seem to have been obsolete. The North-East and South-West zones had TGR of 0.734 and 0.733

respectively. The TGR for the North-East, North-West, South-East, South-South and South-West zones are higher than the TGR of the six geopolitical zones, Nigeria as a whole (pooled) which indicates that if the Nigeria agricultural technology is improved, the zones would be better off (Nkamleu, *et al.,* 2010; Mariko *et al.,* 2019). The comparison of the technological gaps faced by the six geo-political regions of Nigeria as well as Nigeria as an entity revealed that there is a huge productivity potential ratio in the various zones as well as the country as a whole. It is therefore expected that modern and environmentally-friendly technologies and agricultural extension innovations and workshops that will better improve the productivity of the food crop production enterprises by bridging the gaps in technologies be patronized in all the geo-political zones of the country. From the policy point of view, the difference in the various zones provide an insight into what is to be put in place to improve the efficiency level of Nigeria's agricultural sector. For instance, in the North Central, new technology and efficiency level should be raised. The North West needs improved technical know-how in order to improve their productivity. The agricultural potential of the Northern region of Nigeria needs to be improved by providing them with new technology because they have the potential of feeding Nigeria and the whole of West Africa. They are also endowed with more than 90% of the irrigable lands in Nigeria which means they can produce agricultural products throughout the year but have not been harnessed to its full potential.

CONCLUSIONS

From the major findings of this study, it was concluded that the food crop farmers in all the six geo-political zones are within the active age (41-50) years, and are small scale farmers with very low literacy level. The food crop farmers are not technically efficient in all the six geo-political zones of Nigeria. Hence, there is a huge productivity potential ratio in the various zones of the country. Based on the meta-frontier, at the given level of technology, the food crop farmers were only able to produce 40.3% of the country's potential output. The difference in the mean technical efficiency and meta-production model of food crop farmers showed a huge productivity potential ratio in the various zones of the country. Age, plot size, access to credit and plot ownership were the main determinants of food crop productivity in Nigeria. However, we recommend youth empowerment in agriculture through financial motivation and support with farm machineries. Strengthening farmers' existing cooperative societies for the quality and ease of disbursement of soft loans and credit to promote large-scale food crop production enterprises; organizing and supervising adult educational programmes for the food crop farmers in all the six zones to ease and enhance the adoption of available agricultural extension innovation practices; and introducing, interpreting, adopting and internalizing better and affordable environmental-friendly technologies to enhance the productivity of the food crop production enterprise, due to the existence of large technological gap ratios (TGRs) in all the geo-political regions of the country.

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