Estimating Technical Efficiencies and Productivity Gaps among smallholder farmers in and around FADAMA farming communities of South-Western Nigeria

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Abstract: This paper compares technical efficiencies (TEs) and productivity gaps for farms in Ogun and Oyo States in Southwest Nigeria, accounting for differences in FADAMA and non-FADAMA farming communities. Technical efficiency was estimated using the non-parametric mathematical programming (Data Envelopment Analysis-DEA) approach to the frontier estimation. The productivity/TEs gaps were estimated from the maximum attained and average TEs. The overall predicted average TE of respondents is 37.89%. The estimated productivity gaps for farms in the FADAMA (FFV) and non-FADAMA (FNFVs) villages are 58.63% and 63.17% respectively. The gaps are wider for the FNFV than for the FFV. There are differences between the overall sample and each of the samples of Ogun and Oyo States in terms of the determinants of the TE scores. However, important determinants of TEs are: extension contact, distances to the markets, the use of ICT assets, especially mobile telephone, radio and television, which are crucial to getting information on general agricultural production (including pre and post harvest) and market for inputs and outputs. These are critical policy indicative variables which need urgent attention. Also, encouraging younger folks to adopt more of the FADAMA crop practices (which prove to enhance productivity) is also important.

***Keywords**: DEA, Extension, FADAMA, Productivity, South-western Nigeria*

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1. Introduction

The possibilities of achieving the desired level of agricultural productivity in the past were indescribable owing to the fact that innovative technologies were introduced to Nigerian agricultural system [1]. With the number of technologies developed and disseminated in the country through the research–extension-farmers' linkage system in the past decades, most of the farmers in Nigeria are yet to achieve the desired levels of productivity which would have been possible by using improved technologies developed over the past decades. Judged in terms of technological institutions, research institutions, faculties of agriculture in the universities, the technological base on Nigeria cannot be said to be weak. Improving productivity and output quality requires a functioning system of technology generation and transfer and a means to implement these technologies. Extension services can provide the proper institutional system to deliver these trainings to farmers. In effect, one of the ways to achieve this is to assess the critical aspect of agricultural productivity gap among the different groups of farming communities and the factors responsible for this.

A review of existing literature on the efficiency of resource use and farm productivity reveals a gap in the existing research efforts. Some contributors have concluded that traditional farmers are quite efficient given the resources and technology available to them [e.g. 2-3]. This view has probably been responsible for our agricultural development focus with high capital investment content at the expense of those of the divisible inputs approach. Despite this focus, the nation is yet to find acceptable solution to Nigeria's food production problem. The provision of agricultural extension services has been justified in the literature [e.g 4-5] on both equity and efficiency grounds. In the presence of market failures, for example, externalities, limited access to credit or non-competitive market structures, producers will not face the correct incentives to produce certain varieties. In Nigeria, several intervention programmes aimed at boosting smallholders' productivity have not been seen to create the necessary extension environment that will render the required services effective in improving the farmers' technical efficiency. In view of this, the coming on board of the FADAMA project has incorporated what stakeholders' term "advisory services" which makes participation in the programme all inclusive. The advisory services, in addition to creating awareness on the required inputs, also maintains induced activities which include the use of improved varieties by the FADAMA farmers and use of recommended extension techniques and practices.

The name FADAMA was derived from a *Hausa* word denoting a flood plain or a low-land by the river course which becomes flooded when the river is high. [6] view FADAMA as flood plain accentuated by shallow aquifers and found along Nigeria's river system. FADAMA project is basically collaborations between the World Bank and the Federal Government of Nigeria. The programme was executed in different phases; it was a demand-driven programme which permits the beneficiaries the privilege of making the decision that will affect their activities. National FADAMA Development Programme (NFDP) mainly focused on how to sustainably increase the incomes of all-inclusive FADAMA users namely, farmers, pastoralist, fisher folks, hunter, gatherer, and service providers, through empowering communities to take charge of their own development agenda and by reducing conflicts among users [7]. There have been up to 3 FADAMA programmes in Nigeria till date. The FADAMA programme has now diversified into crop and livestock/fishery production, processing, marketing, etc., but crop production aspect is still a major issue because of lack of access to resources/facilities to adopt productivity improving practices. Increased (consistent/sustainable) crop productivity is necessary to boost producers' morals and to feed the storage processing outfits with the required amount of stocks/raw materials.

A number of studies have been conducted on the impacts of the FADAMA (especially FADAMA II) projects. Some of these studies include: [8-11]. It has been noticed that most of them were critical about the poverty, economic and social impacts of FADAMA on the participating stakeholders. However, these studies have been silent on key and specific areas of farmers' productivity as they are affected by the various extension technologies, particularly the aspect of extension practices which are either generated or promoted through the implementation of the FADAMA projects. There is therefore the need to assess the technical efficiencies (TEs) resulting from the use of the extension practices in the FADAMA environment and also determine the productivity gap arising from the differences in the TEs of the States considered.

This paper contributes to literature in a number of ways. First, in contrast to many of the FADAMA studies which only considered the poverty, economic and social impacts of FADAMA on the participating stakeholders, e.g. [8-11], we investigated the technical efficiency differences between the considered States and proceeded to examine the productivity gap therefrom. Second, we used a large data set which ensured representativeness in all forms, enabling us to separately determine the factors that influenced the technical efficiencies of the farmers. These factors are deemed to be responsible for the heterogenous and homogenous differences in the pooled and the disaggregated samples.

The rest of the paper is organised as follows: In section 2, the relevant literature is briefly reviewed and the analytical framework describing the econometric models is presented. Section 3 discusses the methodology which comprises the study area, sampling and sample size; the data and variables.

2. Literature Review and Analytical Framework

2.1 Literature Review

One of the major challenges faced by farmers in Sub-Sahara Africa (SSA) is the problem of increasing agricultural productivity. Agriculture is pragmatically the main means of livelihood for most families in this region [12]. Careful observation of the agricultural production trend in SSA since 1960s shows that it has suffered from matching up with the increasing population growth [13]. Improving the productivity, profitability, and sustainability of smallholders' farming is therefore the mainpathway to get out of poverty [14]. It is widely argued that, achieving agricultural productivity growth will not be possible without developing and disseminating improved agricultural technologies that can increase productivity to smallholder agriculture [15]. Sustainable agricultural extension programmes and projects have been found to be some of the ways by which agricultural productivities can be improved upon. Agricultural extension is an education process which stimulates learning and uses the combined findings of biological sciences and the principles of social science to bring about transformation in knowledge, skill attitude and practices in and out of school setting [16]. It has been asserted [17] that extension is one of the most common instruments of transmitting knowledge and skills to farmers as support to apply them to the real world. [18] also hypothesized that agricultural extension services play a greater role in ensuring that Nigeria achieves the Sustainable Development Goals (SDGs). Extension services can be organised and delivered in a variety of forms, but their fundamental aim is to accelerate farmers' productivity and income which follow the channel of providing information and educating them on how to apply core principles of improved technologies to farm practices [19-20].Therefore, effective extension can contribute to the improvement of agricultural productivity, increased output, and household income for the economy by bridging the gap between educational discoveries in extension providers and the status in individual farmers [21]. According to [19] there can only be the possibility of production improvements when there is a gap between real and potential productivity. They suggest the two 'gaps' types, i.e. *technology gap* and the *management gap* which contribute to the productivity differential. Extension could contribute to the decrease in the productivity differential through an increase in the speed of technology transfer and by improving farmers' knowledge and assisting them in improving their farm management practices [22]. However, poor people are benefitting from innovative extension programmes, especially women and people with low literacy levels.

Some studies, e.g. [23-24] also found that extension has contributed to increased productivity and farm income. Studies such as [25-27] measured the impact of extension services by controlling for extension variables, such as number of extension visits and total hours of extension worker time on crop yield per hectare and reported that extension contacts significantly increased the crop production and the value of crop production. However, other studies, e.g. [21 & 28] argue that agricultural extension has limited impacts on farm income and in dealing with agricultural productivity in many African countries. In other words, the effect of extension services in developing countries has been found to still be weakly functioning.

2.2 Analytical Framework

Data Envelopment analysis (DEA) and fractional zero & one-inflated beta models were used to analyse the data collected. DEA was used to investigate the distribution of technical efficiency (TE) scores, the mean TEs, the minimum and maximum TEs for the overall and States' samples. The technical/productivity gaps were estimated from the maximum attained TEs and the average TEs. The fractional (zero and one-inflated beta) regression model was used to investigate the determinants of (factors affecting) TEs.

2.2.1 Estimation of Technical Efficiency and Productivity Gap

A couple of methods to model efficiency and productivity exist. Earlier, [29-30] independently proposed the stochastic frontier production function as follows:

$$y_i = f(x_i;\beta) + e_i \quad \text{where } i = 1, 2, \ldots\ldots, N \tag{1}$$

$$e_i = v_i - u_i \tag{2}$$

where y_i represents the level of output of the *i*th firm; $f(x_i;\beta)$ is an appropriate production function of vector x_i of inputs for the *i*th firm and a vector, β, of parameters to be estimated. e_i is an error term which comprises two components: v_i which is a random error with zero mean and is specifically associated with random factors like measurement errors in production as well as weather factors that the crop farmers cannot control and it is assumed to be symmetric and independently distributed as $\mathrm{N}(0;\sigma^2 v)$, random variables and is independent of u_i. Conversely, u_i which ranges from zero to one, is a *non-negative* truncated half normal, $\mathrm{N}(0;\sigma^2 u)$, random variable and is linked to firm specific characteristics, which leads to the *i*th firm not achieving maximum production efficiency. *N* is the number of firms in the cross-sectional sample. The stochastic frontier production function can be estimated by the maximum likelihood estimation (MLE) technique [31]. A couple of studies which employed the approach describe above abound. For example, according to [32], within the framework of the stochastic production frontier, a parametric methodology was earlier proposed by [33] and applied by [34-36] to estimate the scale efficiencies in their studies. Other studies which are related to stochastic frontier analysis (SFA) are [37-39]. These studies employed stochastic frontier production approaches to estimate efficiency and productivity gaps, productivity and efficiency and efficiency technological gap respectively.

The computation of technical efficiency (TE) in the econometrics literature is based on either input-oriented or output-oriented analysis [40]. Parametric and non-parametric methods are the approaches widely applied in the estimation of the TE [41-42]. The choice between the two depends on the objective of either input minimization or output maximization, without changing any of the other elements [43]. SFA models [42] make use of the input-oriented production functions which are parametric in nature (equations 1 and 2). In the present study however, our data are amenable to the non-parametric method to generate the efficiency scores. To estimate the production efficiencies (TEs) of the respondents, the non-parametric approach or mathematical programming method which focuses mainly on the Data Envelopment Analysis (DEA) was employed. The following expressions explain the estimation procedure, following [44] and modified and adopted by [45-46]:

$$\min_{\phi_i \lambda_j} \phi_i,$$

$$st{:}\ y_{ri} - \sum_{j=1}^{n} Y_{rj}\lambda_j \le 0, r = 1, \ldots\ldots\ldots\ldots\ldots.., s$$

$$\theta_i x_{ik} - \sum_{j=1}^{n} X_{kj}\lambda_j \geq 0, k = 1, \ldots\ldots\ldots\ldots\ldots.., m$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j \geq 0, \; j = 1, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots., n \qquad (3)$$

Where θ_i denotes the technical efficiency of the i^{th} firm. This i^{th} firm uses m inputs set x_{ik} (m represents stocking density, planting materials, labour, costs of other relevant inputs) to produce s output set y_{rj} (s represents different types of farm product: maize, yam, guinea corn, soybean, groundnut, cowpea, melon, leafy vegetables, tomato, okra, pepper, onion); m is the number of outputs (r=1…s); n is the number of inputs (i=1…..m); λ_j is a non-negative vector that permits the construction of a production possibility set for j DMU; Y_{rj} is a vector of output level; X_{kj} is a vector of observed inputs.

It was necessary to investigate the determinants of TEs. To achieve this, 'fractional' regression models, which make use of fractional response variables (and can effectively be modeled) were deemed appropriate. To some appreciable extent, fractional models are related to binary response models [47]. Instead of estimating the probability of being in one bin of a dichotomous variable however, the fractional model deals typically with variables that take on all possible values in the unit interval. The generalization of this model can easily be done to take on values on any other interval by appropriate transformations [48]. Two approaches to modeling this problem exist. The two approaches, which even (they) though (both) rely on an index that is linear in x_i combined with a link function [49], this is not strictly necessary. The first approach uses a log-odds transformation of y as a linear function of x_i, i.e., $\log \frac{y}{1-y} = x\beta$. This approach appears to be problematic and the reasons are distinctly twofold: firstly, the y variable cannot take on boundary values 1 and 0, and the interpretation of the coefficients is not straightforward. Secondly, the approach circumvents these issues by using the logistic regression as a link function. More specifically,

$$E[y \vee x] = \frac{\exp(x\beta)}{1 + \exp(x\beta)} \qquad (4)$$

It immediately becomes clear that this set up is very similar to the binary logit model, with that difference that the y variable can actually take on values in the unit interval. Many of the estimation techniques for the binary logit model, such as non-linear least squares and quasi-MLE, carry over in a natural way, just like heteroskedasticity adjustments and partial effects calculations [48]. Extensions to this cross-sectional model have been provided that allow for taking into account important econometric issues, such as endogenous explanatory variables and unobserved heterogeneous effects. Under strict exogeneity assumptions, it is possible to difference out these unobserved effects using panel data techniques, although weaker exogeneity assumptions can also result in consistent estimators [49-50]. Two step control function techniques to deal with endogeneity concerns have also been proposed [51].

A couple of studies have applied fractional regression models and their variants in handling fractional response variables. Some of these studies include [49-50; 52-55]. Given the nature of our data, the variant of fractional (zero and one-inflated beta) regression model was used to investigate the determinants of (factors affecting) TEs.

3. Methodology

3.1 Study area, sampling and sample size

South west Nigeria has 6 States; Ekiti, Lagos, Ogun, Ondo, Osun and Oyo. It is majorly a *Yoruba* speaking area, although there are different dialects even within the same State. The weather conditions vary between the 2 distinct seasons in Nigeria (The rainy season is usually between March and October/November and the dry season between November and February). The south west Nigeria is also known as the south west geographical zone of Nigeria. It lies between longitude 2°311 and 6°001 East and Latitude 6°211and 8° 371N [56] with a total land area of 77,818 km^2. The study area is bounded in the East by Edo and Delta states, in the North by Kwara and Kogi states, in the West by the Republic of Benin and in the south by the Gulf of Guinea.

The study was conducted in 2 out of the 3 South Western FADAMA beneficiary states of Lagos, Ogun and Oyo. Ogun and Oyo States were selected in the first stage of the sampling (Lagos state was excluded during the selection process because the state is mainly metropolitan and has insignificant number of rural and farming settlements). In the second stage, 6 local government areas (LGAS) were randomly selected from each of the 20 beneficiary LGAs of the selected 2 states (Ogun and Oyo). Using the "Confidence interval" approach [57][1] and a response rate of between 75 and 95 percent, our desired sample size was estimated to be 1013 households. A total number of 1,177[2] copies of questionnaire were eventually distributed to the household heads in the third stage of the sampling process. The proportion to the size 'approach' of each of the two selected states and the 6 LGAs in the population was used to allocate the optimum samples. This sampling method ensured representativeness (in the samples) of communities and households for assessing the technical efficiency and productivity gap of FADAMA crop farmers in South Western Nigeria.

3.2 Data and Variables

Data used in the study were mainly primary and they were obtained through a cross-sectional survey conducted to collect farm level data on agricultural production variables in 2019. The variables (among others) which were collected included; seed use, land use, labour (family, hired and contractual), tractor hiring, various types of fertilizers, other agrochemicals

[1] See also [58].

[2] Realized/achieved sample size

(insecticides, herbicides, fungicides etc). Also, data on other crops grown, farming systems, quantity of maize/rice produced, quantity consumed, quantity marketed and extension practices were also collected. The data used in the analysis contain one output (*y*) which is in monetary value of crops like maize, yam, guinea corn, soybean, groundnut, cowpea, melon, leafy vegetables, tomato, okra, pepper, onion. These crops were planted either singly or in combination with other crops by each of the respondents. Four explanatory variables were included in the function; they were planting materials, labour, chemical and farm size. These variables (except for farmize) were also transformed into their monetary values. In Table 1, Oyo State recorded higher mean output value and labour cost than Ogun State, while Ogun State recorded higher mean costs for planting materials and chemicals. Mean farm sizes were also larger in Ogun State than in Oyo State.

Table 1: Descriptive statistics (Mean values and standard deviations) of input and output variables

	Total Sample (n=1,177)		Ogun State (n=624)		Oyo State (n=553)	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
Output (Naira)	114606.70	71165.20	111878.20	56313.99	117685.50	84808.49
Planting materials (Naira)	30643.48	31471.95	334007.81	38265.60	27524.23	20956.68
Total labour cost (Naira)	38309.11	56073.10	24296.25	48233.95	54121.09	60002.47
Chemical cost (Naira)	81134.79	42098.05	83447.04	35084.12	78525.68	48719.33
Farm size (Hectare)	4.34	3.16	4.98	3.94	3.605244	1.67

4. Results and Discussion

4.1 Technical efficiency distribution (Data Envelopment Analysis-DEA)

The estimation of the technical efficiency for this study was done using the non-parametric mathematical programming approach to the frontier estimation. The results revealed that there is high variation among the efficiency levels of the farmers in the study area. The distribution of the efficiency scores among the farms is not uniform, (i.e. it’s not about the mean, having) the least score of 0.032 and the highest of 1.000 with mean of 3.79. The farms with scores less than 0.5 (TE<0.5) are certainly not efficient while those of scores 0.5 and above (TE≥0.5) are efficient. Results in Table 2 indicate that 80.74%, 78.92% and 81.91% for the pooled sample, farms in Ogun and Oyo States respectively are not efficient. The highest number of farms, i.e. 26.25%, 25.50% and 26.92% for the pooled sample, Ogun and Oyo States are with technical efficiency that fall between 29 and 39 percent score. Results further revealed that only 48(4.08%), 64(10.26%) and 84(15.19%) farms for pooled sample, Ogun and Oyo States with an index of 1, are operating at 100 percent technical efficiency. The estimated technical efficiencies

(TEs) showed that the predicted average TEs of respondents were 37.89%, 45.43% and 48.22% for the pooled Ogun and Oyo State samples respectively. This shows that the observed outputs are 37.89%, 45.43% and 48.22% less than the maximum output which can potentially be achieved from the existing level of inputs. This also accounts for the levels of inefficiency for an average farmer in the study area. The least efficient farmer has an index of 0.032. For the pooled sample, the average TE was 37.89%. This suggests that farmers in the study area were not technically efficient in their use of resources. The results however imply that the sampled farmers in the study area could increase production by as much as 62% utilizing existing resources and technology. As shown in Table 2, respondents had efficiency scores ranging from 5.54% to 100% in Ogun State and from 3.22% in Oyo State and the pooled sample. This result is quite inconsistent with other studies, for instance, [59-60]. This could be due to the smaller sample sizes in their studies and also to the differences in environmental conditions of the research sites.

Table 2: Frequency distribution of TE scores for Ogun, Oyo States and pooled sample

	Ogun		Oyo		Pooled	
TE scores (%)	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
0< TE≥9	27	4.33	28	5.06	55	4.67
9< TE≥19	111	17.79	116	20.98	227	19.29
19< TE≥29	88	14.10	67	12.12	155	13.17
29< TE≥39	168	26.92	141	25.50	309	26.25
39< TE≥49	98	15.71	101	18.26	199	16.91
49< TE≥59	23	3.61	21	3.80	44	3.74
59< TE≥69	32	5.13	22	3.98	54	4.59
69< TE≥79	20	3.21	12	2.17	32	2.27
79< TE≥89	12	1.92	7	1.27	19	1.61
89< TE≤100	45	7.21	38	6.87	83	7.05
Total	624	100.00	553	100.00	1177	100.00
Mean TE	45.43%		48.22%		37.89%	
Min. TE	5.54%		3.22%		3.22%	
Max. TE	100%		100%		100%	

4.2 *Technical Efficiency (Productivity) gaps associated with the use of the extension practices*

Next, the presence of productivity (TE) gaps was investigated (Table 3). This is captured by the difference between maximum attained and the average TEs by each of the samples[3] of farmers in FADAMA village (FFV) and farmers in non-FADAMA village (FNFV).These samples are for the pooled, Ogun and Oyo States' farms. Results indicate the presence of productivity gaps for FFV and FNFV farms of the pooled, Ogun and Oyo States' samples. The values of the gaps are as follows: pooled sample (FFV =58.63%; FNFV =63.17%), Ogun State (FFV=57.94%; FNFV=63.31%) and Oyo State (FFV=59.63%; FNFV=64.36%). In all the samples, the gaps are wider for the FNFV than for the FFV. This implies that the average TEs attained by each of the FNFV farms of the overall and state samples are far less compared than the TEs attained by their FFV counterparts. This result is different from the ones estimated by [37] and [39]. These two studies estimated TE, productivity and their gaps, using the parametric stochastic approaches.

Table 3: Productivity (TE) Gaps

		Pooled		Ogun		Oyo	
		FFV	FNFV	FFV	FNFV	FFV	FNFV
TEs	Average	41.37	36.17	42.06	36.69	40.37	35.64
	Max	100	100	100	100	100	100
GAPS	Productivity (TE) = (Max. TE - Av.TE)	58.63	63.17	57.94	63.31	59.63	64.36

4.3 Determinants of the technical efficiencies

The determinants of technical efficiency were investigated using both the ***zero and one-inflated beta*** models. The model results are presented in Tables 4, 5 and 6. Just as there are differences in the TEs across the pooled, Ogun and Oyo States' samples, there are also differences between the overall sample and each of the samples of Ogun and Oyo States in terms of the determinants of the TE scores. Results for the pooled sample indicate that households in the FADAMA villages (FVs) had fewer extension contact, are male headed, with moderate distance to the nearest market and are associated with increasing TEs. The one-inflation equation showed that the households in the FFVs, having fewer extension contact, being male headed households, ownership of ICT materials and younger household heads are more likely to have the maximum efficiency score of 1 or to be 100% efficient in the use of available resources.

[3] Two categories of firms/firms were considered: 1. FFV denotes farms/firms in FADAMA village and 2. FNFV stands for farms/firms in non-FADAMA village. The FVs and NFVs are FADAMA and non-FADAM villages respectively.

Table 4: Determinants of Technical efficiency (ML fit of oib): Pooled sample

TE scores	Coefficient	Std. Err.	z	P>|z|
Proportion				
FFV/FNFV (FFV=1, FNFV=0)	0.1434216	0.0584512	2.45	0.014
Extension contact (number of times)	-0.1524187	0.0436792	-3.49	0.000
Farmer participation in extension training (1,0)	0.1064116	0.1247673	0.85	0.394
Household size (number of persons in household)	0.0097289	0.0080003	1.22	0.224
Farmsize (ha)	-0.018184	0.0135377	-1.34	0.179
Sex (1=male, 0=female)	0.2982203	0.0781393	3.82	0.000
Distance from farm to nearest market	0.0163035	0.0074035	2.20	0.028
Ease of access to research institute/extension (1,0)	0.025753	0.0363059	0.71	0.478
Easeofaccess to input (1,0)	0.0416034	0.0345796	1.20	0.229
Own ICT material (1,0)	0.0813042	0.0653125	1.24	0.213
Education of household head (years)	-0.0060602	0.0070433	-0.86	0.390
Age of household head (years)	-0.0023284	0.0028911	-0.81	0.421
Creditaccess (1,0)	-0.0388925	0.0679414	-0.57	0.567
Tropical livestock units	-0.0002727	0.000257	-1.06	0.289
Constant	-0.7182071	0.2281245	-3.15	0.002
Oneinflate				
FFV/FNFV (FFV=1, FNFV=0)	0.6187373	0.3586225	1.73	0.084
Extension contact (number of times)	-0.6309895	0.2173578	-2.90	0.004
Farmer participation in extension training (1,0)	-0.3663697	0.7824522	-0.47	0.640
Household size(number of persons in household)	0.0235966	0.0449388	0.53	0.600
Farmsize (ha)	0.0389784	0.0683175	0.57	0.568
Sex (1=male, 0=female)	0.98529	0.4647416	2.12	0.034
Distance from farm to nearest market	-0.0102698	0.0413148	-0.25	0.804
Ease of access to research institute/extension (1,0)	0.0863245	0.2608651	0.33	0.741
Easeofaccess to input (1,0)	-0.0403686	0.201202	-0.20	0.841
Own ICT material (1,0)	-1.004713	0.370603	-2.71	0.007
Education of household head (years)	-0.0557464	0.0431863	-1.29	0.197
Age of household head (years)	-0.0377837	0.0171368	-2.20	0.027
Creditaccess (1,0)	-0.1381498	0.3905623	-0.35	0.724
Tropical livestock units	-0.0147705	0.0220791	-0.67	0.504
Constant	0.6195109	1.282079	0.48	0.629

ln_phi

_cons	1.600407	0.0393182	40.70	0.000
Number of observations	1,154			
Log likelihood	116.19733			
Wald chi^2 (14)	53.52			
Prob> chi^2	0.0000			

Results for the Ogun and Oyo states' samples showed that households in FVs (Ogun), had fewer extension contact (Ogun and Oyo), participated in extension training (Oyo), are male headed (Oyo), with moderate distance to the nearest market (Oyo) and are associated with increasing TEs. On the other hand, the one-inflation equation showed that for Oyo State, households with fewer extension contacts and with younger household heads are more likely to be 100% efficient in the use of available resources.

Table 5: Determinants of Technical efficiency (ML fit of oib): Ogun State

TE scores	Coef.	Std. Err.	z	P>|z|
Proportion				
FFV/FNFV (FFV=1, FNFV=0)	0.1787355	0.0808375	2.21	0.027
Extension contact (number of times)	-0.1522513	0.057864	-2.63	0.009
Farmer participation in extension training (1,0)	-0.1230481	0.1736008	-0.71	0.478
Household size(number of persons in household)	0.013231	0.0106632	1.24	0.215
Farmsize (ha)	-0.0270872	0.0176631	-1.53	0.125
Sex (1=male, 0=female)	0.1776922	0.1146467	1.55	0.121
Distance from farm to nearest market	0.0086653	0.0113448	0.76	0.445
Ease of access to research institute/extension (1,0)	0.078839	0.055089	1.43	0.152
Easeofaccess to input (1,0)	0.0683971	0.0544134	1.26	0.209
Own ICT material (1,0)	0.136276	0.0974636	1.40	0.162
Education of household head (years)	-0.0031415	0.0096909	-0.32	0.746
Age of household head (years)	-0.001606	0.0039614	-0.41	0.685
Creditaccess (1,0)	-0.0625961	0.1008551	-0.62	0.535
Tropical livestock units	0.0053569	0.0057236	0.94	0.349
Constant	-0.6574928	0.3033712	-2.17	0.030
Oneinflate				
FFV/FNFV (FFV=1, FNFV=0)	0.3678674	0.5522508	0.67	0.505
Extension contact (number of times)	-0.2987505	0.3362879	-0.89	0.374
Farmer participation in extension training (1,0)	-0.6633287	1.13457	-0.58	0.559
Household size(number of persons in household)	0.0216404	0.0607307	0.36	0.722
Farmsize (ha)	-0.0515294	0.1149739	-0.45	0.654
Sex (1=male, 0=female)	0.8035649	0.695345	1.16	0.248
Distance from farm to nearest market	0.1124036	0.0841656	1.34	0.182
Ease of access to research institute/extension (1,0)	0.2664969	0.4077026	0.65	0.513
Easeofaccess to input (1,0)	-0.1465451	0.3322019	-0.44	0.659
Own ICT material (1,0)	-1.276749	0.5583239	-2.29	0.022

Education of household head (years)	-.0725433	0.0596444	-1.22	0.224
Age of household head (years)	0.0023596	0.0232639	0.10	0.919
Creditaccess (1,0)	-0.4458433	0.6040382	-0.74	0.460
Tropical livestock units	-0.0120546	0.0457481	-0.26	0.792
Constant	-2.245889	1.737456	-1.29	0.196
ln_phi				
Constant	1.551795	0.0533953	29.06	0.000
Number of obs.	618			
Log likelihood	54.307415			
Wald chi^2 (14)	35.34			
Prob> chi^2	0.0013			

Table 6: Determinants of Technical efficiency (ML fit of oib): Oyo State

TE scores	Coef.	Std. Err.	z	P>|z|
Proportion				
FFV/FNFV (FFV=1, FNFV=0)	0.098914	0.0874147	1.13	0.258
Extension contact (number of times)	-0.1397527	0.0668609	-2.09	0.037
Farmer participation in extension training (1,0)	0.4013546	0.2052679	1.96	0.051
Household size(number of persons in household)	0.0048879	0.0121271	0.40	0.687
Farmsize (ha)	0.0052816	0.0254506	0.21	0.836
Sex (1=male, 0=female)	0.4140183	0.1137313	3.64	0.000
Distance from farm to nearest market	0.0215261	0.0103449	2.08	0.037
Ease of access to research institute/extension (1,0)	-0.0123239	0.0570965	-0.22	0.829
Easeofaccess to input (1,0)	0.0476016	0.0475187	1.00	0.316
Own ICT material (1,0)	0.0482498	0.0879516	0.55	0.583
Education of household head (years)	-0.008082	0.0103302	-0.78	0.434
Age of household head (years)	-0.0035565	0.0042575	-0.84	0.404
Creditaccess (1,0)	-0.0297655	0.0946018	-0.31	0.753
Tropical livestock units	-0.0002746	0.0002548	-1.08	0.281
Constant	-1.018759	0.3890628	-2.62	0.009
Oneinflate				
FFV/FNFV (FFV=1, FNFV=0)	0.7441377	0.5147652	1.45	0.148
Extension contact (number of times)	-1.054119	0.321286	-3.28	0.001
Farmer participation in extension training (1,0)	0.0058233	1.204475	0.00	0.996
Household size(number of persons in household)	.0334987	0.627	0.068897	0.49
Farmsize (ha)	0.0123573	0.1232549	0.10	0.920
Sex (1=male, 0=female)	0.8849852	0.6936199	1.28	0.202
Distance from farm to nearest market	-0.0929305	0.0621035	-1.50	0.135
Ease of access to research institute/extension (1,0)	-0.1682131	0.3875922	-0.43	0.664
Easeofaccess to input (1,0)	-0.0865243	0.2703922	-0.32	0.749
Own ICT material (1,0)	-0.6563665	0.5048519	-1.30	0.194

Education of household head (years)	-0.0594067	0.0701246	-0.85	0.397
Age of household head (years)	-0.0838697	0.0265939	-3.15	0.002
Creditaccess (1,0)	0.1773629	0.5522035	0.32	0.748
Tropical livestock units	-0.0228991	0.0281543	-0.81	0.416
Constant	4.58504	2.199975	2.08	0.037
ln_phi				
_cons	1.684881	0.058225	28.94	0.000
Number of obs.	536			
Log likelihood	76.909926			
Wald chi^2 (14)	26.33			
Prob> chi^2	0.0235			

5. Conclusions

This study was conducted to estimate the technical efficiencies (TEs) of farmers in and around FADAMA farming communities in Ogun and Oyo States. The study also determined the productivity gaps arising from the technical efficiency differences and investigated the determinants of TEs. The study found out that farmers in the study area were not technically efficient in their use of resources. They could however increase production by as much as 62% utilizing existing resources and technology. Therefore, farmers should be educated on the importance of making good and optimum use of available resources to improve their output and thereby increasing their efficiency level. The TE/productivity gaps are wider for the households in non-FADAMA villages than for households in the FADAMA villages. Bridging the productivity gaps will require an improvement in farmers' TE levels. Policy makers, including FADAMA stakeholders need to facilitate the processes and methods of achieving this. Findings from this study indicate that to improve efficiency, there is need to encourage more farmers in the study area (particularly farmers in the non-FADAMA villages) to adopt one or more of the management practices in use in the FADAMA villages. Increased access and contact with extension should also be facilitated. It was discovered that households with moderate or shorter distances to the markets were likely to be maximally efficient. The implication of this is that even though physical market distances cannot be shortened, consistent maintenance of the rural feeder roads and those that lead to markets is very critical. This will minimize the time spent on roads and also reduce transportation cost. Also, the farmers should be encouraged and mobilized to prioritize the use of ICT materials in order to boost their information gathering strategies. This is very essential in the sense that ICT materials, especially mobile telephone, radio, television are assets which can be employed to get linked to information on input availability, general agricultural production (including pre and post harvest) and market for inputs and outputs. Younger household heads should also be encouraged to go more into farming by providing them with the necessary incentives. They should also be encouraged to adopt more of the extension practices that have been proven to result into better productivity.

The empirical analysis in this paper are based on a rich data set collected in 2019 on adoption of agricultural extension practices among households in the FADAMA farming communities in

Southwestern Nigeria. These data are worthy of further analyses on the aspects of the types of extension practices vis-à-vis crop and livestock farming in the area. In this paper, we have assumed that productivity and its gaps can be measured on the basis of the efficiency differences resulting from whether households are in the FADAMA or non-FADAMA villages. More research is needed to better understand the nature of the productivity and its gaps on the basis of households adopting one or the combination of the extension practices and what factors are likely to influence this.

Acknowledgements

We gratefully acknowledge the efforts of our field assistants for their efforts in the data collection. We also appreciate staff members of the faculty of Agricultural Sciences, graduate and undergraduate students of the Ladoke Akintola University of Technology, Ogbomoso, Nigeria for their useful criticisms, comments and suggestions during the seminar where the draft of this was presented.

Funding

The research work from which this paper was written was supported by the Tertiary Education Trust Fund (TetFund). The authors acknowledge the Academic Planning Unit of the Ladoke Akintola University for facilitating the release of the fund for the research work.

Competing interests

The authors declare that they have no competing interests.

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