

Production Efficiency Analysis of Irish Potato Farmers in some selected Local Government Areas of Plateau State, Nigeria

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Abstract: This study analysed production efficiency of Irish Potato farmers in some selected Local Government Areas (LGAs) of Plateau State, Nigeria. A multistage random sampling technique was used in selecting the sample size for this study. The primary data collected were analysed using double bootstrap Data Envelopment Analysis (DEA) and truncated regression. Results of the Variable Return to Scale (VRS) DEA shows average technical efficiency (TE) for radial, non-radial and bias-corrected estimates to be 0.90, 0.70 and 0.68, respectively. The mean allocative and economic efficiency levels were found to be 0.74 and 0.64 respectively. The estimated radial TE scores were higher than the bias-corrected TE scores indicating overestimation of the radial scores. The regression result shows age, household size, extension contact and transportation costs have significant effects on technical efficiency while farming experience has significant influence on economic efficiency of farmers. In conclusion the Irish Potato farmers were operating below the production possibilities frontier, indicating there is room for efficient use of input resources. The study, therefore, recommends availability of input resources at affordable rate to Irish potato farmers and training of the farmers on effective inputs resource management as a potential measure to enhance their farm-level production efficiency.

Keywords: bootstrapping, data envelopment analysis, Irish potato farmers, technical efficiency, truncated regression

INTRODUCTION

Irish potato (*Solanum tuberosum* L.) is a globally important tuber plant producing high yields of nutritionally valuable food in form of tubers that belongs to the family Solanaceae. The crop was first cultivated in South America and easily substitutes for cereals in many developing countries; making it very crucial for food security. Global output of Irish potato is about 388 million metric tonnes with an average yield per hectare of 20,110.8 kg/ha (Obi-Egbedi & Gulak, 2020). Over half of the global output is produced in developing countries; almost one-third of the output is harvested in China and India alone, while China is the leading producer in the world with 99 million metric tonnes (Obi-Egbedi & Gulak, 2020). Irish potato production in Africa is estimated at 25 million metric tonnes with average yield per hectare of 13,215.4 kg/ha, and per capita consumption of 18.76 kg/capita/year (FAO, 2021). Based on global ranking, Algeria is the leading producer of Irish potato in Africa with a production of 4,606,400 metric tonnes, followed by Egypt (4,325,480 metric tonnes) and South Africa (2,450,540 metric tonnes). Nigeria's production of 1,284,370 metric tonnes ranks seventh in Africa after Morocco (1,924,870 metric tonnes), Tanzania (1,749,201 metric tonnes) and Kenya, the fourth to sixth largest African producers of Irish Potato (FAO, 2020).

The crop is one of the major sources of income for the rural farmers in Plateau State, and in many other African producing communities (Hudu *et al.*, 2023). About 95 percent of the total Irish potato produced in Nigeria comes from Plateau State; because the weather condition in the state is suitable for Irish potato production. Other Irish

potato producing areas such as Obudu in Cross River State, Mambila Plateau in Taraba State, and parts of Kaduna State account for the remaining 5 percent (Hudu *et al.*, 2023). The crop can be processed into other Potato food products such as chips, crisps and flour, and also used as food ingredients. Non-food uses include starch for industry, animal feed, glue as well as seed tubers for planting (Uche *et al.*, 2020).

Although Nigeria despite being the seventh largest producer of Irish potato in Africa, and with the potential of Irish potato production for economic growth and sustainability, domestic Irish potato production has not increased sufficiently to meet the increasing demands. The demand for Irish potato in Plateau and Nigeria at large is however growing faster than expected, with consumption broadening across all socio-economic class. Thus, Irish potato farmers in Plateau State are not getting optimum return from the resources committed to their Irish potato production due to their inefficiency in the use of available resources.

There are considerable numbers of Irish potato specific studies (Wuyep *et al.*, 2013; Zemba *et al.*, 2013; Jatbong, *et al.*, 2018; Panwal, 2018; Obi-Egbedi & Gulak, 2020;) in Plateau State coupled with the evidence of existing few efficiency studies in particular such as Jwanya *et al.*, 2014 on technical efficiency of Irish potato farmers: a stochastic frontier approach; Obi-Egbedi & Gulak (2019), a comparison study on performance of Translog and Cobb-Douglas models in estimation of technical efficiency in Irish potato production, and Hudu *et al.*, (2023) on economic efficiency of small-scale Irish potato farmers in Nigeria and Kenya. But this study analysed the productive efficiency of Irish

potato farmers in the five LGAs majorly known for Irish potato production using double bootstrap data envelopment analysis (DEA) approach. Based on that, the specific objectives were to estimate the levels of technical, allocative and economic efficiency scores of Irish potato farmers, and also to determine the factors influencing technical, allocative and economic efficiency of Irish potato farmers.

METHODOLOGY

Study area - The study area is Plateau State, which is located in the North Central Nigeria. The State lies between Latitude 8° North and 10° North and Longitude 7° East and 11° East of the prime meridian (Uche *et al.*, 2020). The State covers a land area of approximately 26,026 km² with a total population of 3,206,531 and a population density of 103.73 persons per km² based on the 2006 census figure, as well as their 2020 projected population of 5,400,974 with a population density of 174.67 per km² (National Bureau of Statistics NBS, 2020). Plateau State comprises 17 Local Government Areas. The climate on the plateau is tropical but cooler than the surrounding lowlands (Uche *et al.*, 2020). The State is about 1,250m above sea level, and has a near temperate climate with an average annual temperature range from 13 °C to 22 °C in the study area which is required for sprouting of the Irish potato tubers. The warmest temperature usually occurs in the dry season months of March and April while the coolest month is between December and February (Malum & Damwesh, 2023). The mean annual rainfall varies from 131.75cm in the Southern part to 146 cm on the Plateau in the Northern part, and the main cash crop grown in the study area aside Irish Potato includes Maize, Finger-millet, Yam, Wheat, Barley, and Sorghum.

Sampling procedure and sample size - multi-stage random sampling procedure was adopted for this study to select Irish potato farmers from the five (5) major Irish potato producing Local Government Areas (LGAs) in Plateau State, Nigeria. The first stage involved purposive sampling of five (5) major Irish potatoes producing LGAs out of the 17 LGAs in Plateau State based on relative production capabilities, concentration of Irish potato farmers as well as weather adaptability. These selected LGAs include: Barkin-ladi, Bokkos, Jos South, Mangu and Riyom. The next stage involved a simple random sampling of five (5) districts from each of the five (5) LGAs based on productivity level, giving a total of twenty-five (25) districts. The

last stage involved a random sampling of Irish potato farmers from the 25 districts in proportion to their size. Thus, a total of three hundred and sixty-three (363) Irish potato farmers were selected for the study. The sample frame of 3,911 farmers constitutes list of Irish potato farmers in the five LGAs obtained from Plateau State Agricultural Development Programme (PADP). The sample size for the study was determined by a simplified formula for proportion developed by Yamane (1967).

$$n = \frac{N}{1+N(e)^2}$$

Where;

n = sample size

N = total population (3911 Irish potato farmers)

e = sampling error (5% = 0.05).

Data collection - This study used primary data, which was collected with the help of trained and experienced agricultural extension agents during the 2022 production season. The information collected were on inputs used and their cost, output produced and output price, while information on the possible factors affecting Irish potato production as established in the literature, as well as the socio-economic characteristics of the Irish potato farmers were also elicited from the respondents with the aid of structured questionnaires.

Analytical approach - Conventional DEA models (radial and non-radial or slack-based measure SBM). To analyse the objectives of this study, the two common types of conventional DEA techniques from the input-oriented approach were applied: radial and non-radial or slack-based measure (SBM). On one hand, the radial DEA model gives the same specified proportional changes by which all outputs (inputs) are increased (reduced) simultaneously to become efficient and does not consider slacks in resource usage directly. On the other hand, a non-radial DEA model known as the slack-based measure of technical efficiency gives a different proportion and can deal directly with slacks in the efficiency estimation (Aung *et al.*, 2021).

Radial DEA measure of technical efficiency scores - Given the output y (Irish potato produced) and inputs set (farm size, seed, fertiliser, labour and herbicides and pesticides and access to credit), the input-based technical efficiency of the DEA framework for the j^{th} Irish potato farmer, TE_j is defined as: $TE_j = \min \theta_j, \lambda \theta_j \dots \dots \dots (1)$

Subject to: $Y_j \leq Y\lambda$, $\theta_j X_j \geq X\lambda$, $\lambda \geq 0$, $\sum_{j=1}^N \lambda_j = 1$

Where; θ_j = the technical efficiency scores with $0 \leq \theta_j \leq 1$. If $\theta_j = 1$, the farm is technically efficient.

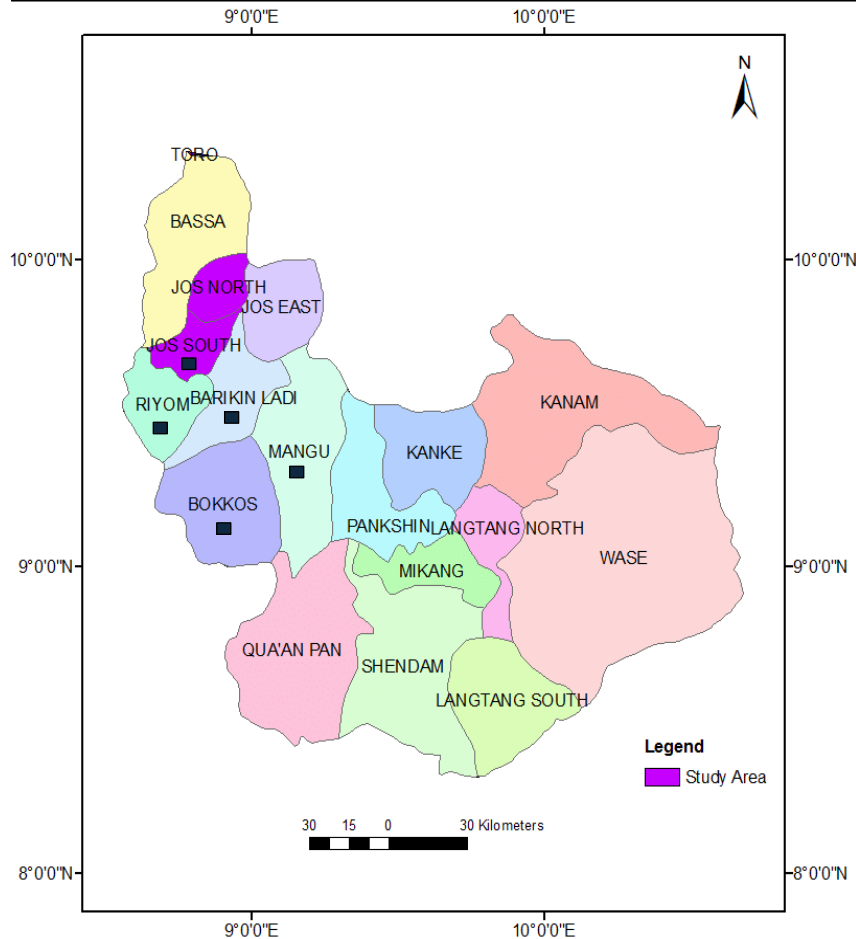


Figure 1: Map of Plateau State Nigeria showing the selected study area
Source: Department of Geography and Planning, University of Jos, 2022.

The vector λ is an $N \times 1$ vector of weights that defines the linear combination of the peers of the j^{th} farm. The first constraint in equation (1) is with respect to the output of the Irish potato farmers. Y_j , tonnes (t) of Irish potato produced per farm in previous production cycle, is the actual level of output of the j^{th} farm compared with the theoretically efficient farm ($Y\lambda$) output vector. The second constraint concerns the inputs of Irish potato produced. Seven main inputs used per farm in previous production cycle, namely; X_1 = farm size (hectares), X_2 = quantity of seed (kg), X_3 = fertiliser (kg), X_4 = labour (man-days), X_5 = herbicide (litres), X_6 =pesticides (litres), X_7 =access to credit (amount accessed ₦), are incorporated into the VRS DEA model in equation (1). $\theta_j X_j$ = the actual level of input used by the j^{th} farm multiplied by its level of efficiency (θ_j). $X\lambda$ = the minimum input use of the theoretically efficient Irish Potato farmers, given the actual level of output produced by the j^{th} farmer. If the solution in equation (1) is smaller than one, the quantity of input used by that Irish potato farmer can be reduced to as low as $X\lambda$ to produce the same level of output. If the solution in equation (1) turns out to be $\theta_j = 1$, that Irish potato farmer's inputs level is as small as the level of input used by the theoretically

efficient farmer at a given same level of output. The third constraint in equation (1) is the convexity constraint, $\sum_{j=1}^N \lambda_j = 1$ for assuming the variable returns to scale (Coelli *et al.*, 2005).

Non-radial DEA or slack-based measure (SBM)

In order to capture the percentage of reduction in the use of any individual input, a non-radial DEA or slack-based measure of technical efficiency model was applied, the mathematical properties of which can be found in (Aung *et al.*, 2021). The slack-based measure of technical efficiency method is expressed as follows:

$$\min_{\rho} = \frac{1 - \left(\frac{1}{m}\right) \sum_{i=1}^m s_i^- / x_{ik}}{1 + \left(\frac{1}{s}\right) \sum_{r=1}^s s_r^+ / y_{rk}} \quad (2)$$

Subject to

$$x_{ik} = \sum_{j=1}^n x_{ji} \lambda_j + S_i^{-1}, i = 1, \dots, m$$

$$y_{rk} = \sum_{j=1}^n Y_{rj} \lambda_j - S_r^+, r = 1, \dots, s$$

$$\lambda_j \geq 0, j = 1, \dots, n; \quad S_i^{-1} \geq 0, i = 1, \dots, m;$$

$$S_r^+ \geq 0, r = 1, \dots, s$$

where, ρ denotes the slack-based measure of technical efficiency of decision making units (DMUs) associated with s output set y_{rk} (s = Irish potato produced) and m input set x_{rk} (m = land, seed, fertiliser, labour, and herbicides/pesticides); λ_j = a non-negative vector

that allows the production possibility set construction for DMUs j ; n is the number of DMUs ($j = 1, \dots, n$); S_i^{-1} and S_r^{+} are denoted as slacks associated with inputs x (input excess) and output vector y (output shortfalls), respectively. $S_i^{-1} = 0$ implies no input excess and $S_r^{+} = 0$ implies no output shortage for all i and r .

More so, two additional measurements of efficiency were established, taking into account input prices: allocative and economic efficiency. Allocative efficiency (AE) evaluates farmers' potential to utilise resources in ideal quantities given input prices, whereas the economic efficiency (EE) is a product of technical and allocative efficiency (Hassan, 2021). The economic efficiency is assessed in two steps: firstly, a cost-minimising vector of input quantities is determined, given the input prices under VRS assumption as follows.

$$\text{Min} x_j^*, \lambda \quad w_i', x_i^* \dots \dots \dots (3)$$

Subject to

$$\begin{aligned} -Y_j + Y\lambda &\geq 0, \\ x_i^* - X\lambda &\geq 0, \\ N1' \lambda &= 1 \\ \lambda &\geq 0, \end{aligned}$$

Where; Y_j is the output level and $Y\lambda$ is output vector, $X\lambda$ is input vector. The economic efficiency (EE) of the i -th, farm is then estimated as the ratio of the minimum cost to observed cost,

$$EE = w_i', x_i^* / w_i', x_i \dots \dots \dots (4)$$

Where w_i' is the input price vector for the i -th farm and x_i^* is the cost-minimising vector of input quantities for the i -th farm, given the input prices w_i' .

Residually, the allocative efficiency would be calculated as

$$AE_i = EE_i / TE_i \dots \dots \dots (5)$$

Where, EE_i is the economic efficiency of i -th is farm and TE_i is the technical efficiency of i -th farm. Like TE, the value for AE and EE will be $\leq$ one with highest efficiency equal one and present on frontier.

Truncated regression model

Simar & Wilson (2007) advocated the use of the truncated regression model that considers explicitly the bounded domain of the DEA efficiency estimates. Taking this critique into consideration, this study adopted the truncated regression model as follows:

$$\widehat{\delta}_j = \beta Z_j + \varepsilon_j \geq 1 \dots \dots \dots (6)$$

Where; $\widehat{\delta}_j$ is, called the technical efficiency score with the range from 1 to infinity and Z_j is a vector of individual farm characteristics assumed to affect the choice and use of output and inputs, β is a vector of parameters to be estimated, and ε_j is a continuous random variable, distributed

as $N(0, \delta_\varepsilon^2)$ with left truncation at $1 - \beta Z_j$ for each farm j , and assumed to be independent of Z_j . Adopting the truncated regression for equation (6), this procedure avoids boundary problems since the estimated value of technical efficiencies are typically defined on the interval (0,1), with, in general, few values, if any, close to 0 but some values of 1.

The truncated equation is described as follows:

$$y_i^* = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + \beta_{13} X_{13} + u \quad (7)$$

Where; y_i^* = Latent dependent variable representing the efficiency score for farm i .

X_1 = sex (male = 1, female = 0); X_2 = age (years); X_3 = marital status (single = 1, married = 2, divorced = 3); X_4 = level of education (primary = 1, secondary = 2, tertiary = 3, adult/informal = 4); X_5 = household size (number of household in person); X_6 = primary occupation; X_7 = secondary occupation; X_8 = farming experience (years); X_9 = quality of planting seed (kg); X_{10} = extension contact (weekly = 1, monthly = 2, quarterly = 3, annually = 4); X_{11} = Membership of farm group (yes = 1, no = 0); X_{12} = transportation cost (naira ₦); X_{13} = land acquisition (purchased = 1, rented/leased = 2, inheritance = 3, gift = 4, others specify = 5); X_{13} = access to credit (yes = 1, no = 0), β_0 = constant term, $\beta_1 - \beta_{13}$ = regression coefficients, and u = error term that is independently and normally distributed with zero mean and constant variance σ^2 .

RESULTS AND DISCUSSION

Summary statistics of variables in the models.

Table 1 provides the summary statistics of the inputs and output variables used in estimation of the VRS DEA function. The average production of Irish potato during the season is 63.46 kg/ha with output ranged between 9 to 243 bags/ha. The Irish potato farm size ranged between 0.5 to 3 hectares with a mean of 1.47 hectares. Quantity of seeds used among Irish potato farmers ranged between 1 to 8 kg/ha with a mean of 2.48kg/ha. The fertiliser uses among Irish potato farmers during the season ranged between 1 to 22kg/ha with a mean of 7.78kg/ha. Labour is usually distributed between the various farm operations ranging from land preparation to harvesting of product. The labour used during the season ranged between 2 to 5 man-day/ha with an average of 5.36 man-days/ha. Herbicide used among farmers stood between 2 to 16 litres/ha with a mean of 6.89 litres/ha while that of pesticide ranged between 1 to 9 litres/ha with a mean of 3.12 litres/ha.

Table 1: Summary Statistics of Variables in the DEA VRS Function

Variables	Unit	Mean	Minimum	Maximum
Seed	Bag/kg	2.480 (1.279)	1	8
Farm size	Ha	1.428 (0.584)	0.5	3
Fertiliser	Bag/kg	7.782 (3.822)	1	22
Labour	Man-days	5.368 (3.316)	1.94	4.55
Output	Kg/ha	63.461 (39.236)	9	243
Herbicide	Litre	6.897 (3.026)	2	16
Pesticide	Litre	3.121 (1.457)	1	9
Access to credit	Dummy	0.615 (0.487)	0	9

Source: Field Survey, 2022. Values for standard deviation in parenthesis

Estimation of Irish Potato farm level technical efficiency scores.

Table 2 presents the results of the technical efficiency scores from the input-oriented VRS DEA models.

Table 3: Distribution of Irish Potato Farmers by Technical Efficiency Scores

DEA VRS assumption technical efficiency						
Radial TE Non-radial (Slack-based) TE Bias-corrected TE						
Efficiency Range	Frequency	Percent	Frequency	Percent	Frequency	Percent
< 60	8	6.6	36	29.8	39	32.8
60 – 79	24	19.8	55	45.4	45	37.8
≥80	89	73.6	30	24.8	35	29.4
Total	121	100	121	100	119	100
Efficiency scores						
Mean	0.90		0.70		0.68	
Minimum	0.47		0.37		0.26	
Maximum	1		1		1	
Std. Dev.	0.15		0.17		0.16	

Source: Field Survey, 2022. Std. Dev. = Standard Deviation

Technical efficiency for radial measure ranges from 0.47 to 1 with a mean of 0.90 and standard deviation of 0.15. Thus, the most technically efficient farmer is operating on the frontier in this model. Therefore, if the average Irish potato farmer in the sample was to achieve the technical efficiency level of its most efficient counterpart, then the average Irish potato farmer could reduce 10 percent [i.e. $(1-0.90) \times 100$] of input use without changing output level. A similar calculation for the most technically inefficiency farmer reveals input saving of 53 percent [i.e. $(1-0.47) \times 100$].

However, in the magnitude of the non – radial technical efficiency score under VRS DEA was at an average of 0.70 with a low of 0.37 and a high of 1, with a standard deviation of 0.17. Again, the most technically efficient farmer is operating on the frontier. It suggests that if the average farmer was to achieve the technical efficiency level of its most

efficient farmer, then the average farmer could achieve an input saving of 30 percent while the least efficient farmer would achieve an input saving of 63 percent. So, the feasible input reduction was 30 percent [i.e. $(1 - 0.70) \times 100$]. Theoretically, the average technical efficiency derived from the radial model was 20 percent higher than that obtained through non – radial measure, which means radial measure over-estimated the technical efficiency score because it does not take into consideration the slacks in efficiency estimation, which in turn leads to bias result. In other words, the technical efficiency scores obtained from the input-oriented radial measure is higher than the non-radial measure because the radial measure ignores the possibility of slack that may occur in the constraints but the non-radial approach accommodates such slack in the estimation process and provides more precise technical efficiency scores. This result is in line with the finding of (Bitrus *et al.*, 2020).

The bias-corrected technical efficiency (BCTE) ranges from 0.26 to 1 with a mean of 0.68, and a standard deviation of 0.16. Again, the most technically efficient farmer is operating on the frontier. This average score of the BCTE highlights that there is substantial potential for input reduction at 32 percent [i.e. $(1 - 0.68) \times 100$]. This further suggests that if the average Irish potato farmer was to achieve the technical efficiency level of its most efficient Irish potato farmer, then the average Irish potato farmer could achieve an input saving of 32 percent while the least efficient farmer would achieve an input saving of 74 percent. Conversely, on average Irish potato farmers can increase their current output level by 32 percent without increasing the existing levels of inputs. This implies Irish potato farmers on average could decrease input use by 32 percent to get the output they are currently

getting if they use inputs efficiently. This result aligned with the work of Anang *et al.* (2020), with technical efficiency estimate under CRS, VRS and bias-corrected technical efficiency scores of 0.52, 0.72 and 0.57, respectively in smallholder maize production in Northern Ghana. The findings also are in accordance with the study of Kirimov (2013), who estimated non-bias and bias-corrected efficiency scores of 67 percent and 59 percent respectively, for Potato farm in Uzbekistan but contradict the study of Anang *et al.* (2020), who reported a higher bias-corrected technical efficiency score.

Estimation of allocative and economic efficiency scores for Irish potato farmers

Table 3 presents the results of the allocative and economic efficiency scores of Irish Potato farmers obtained from VRS-DEA model.

Table 3: Distribution of Allocative and Economic efficiency Scores Irish Potato Farmers

DEA VRS assumption efficiencies estimate				
Allocative Efficiency AE	Economic Efficiency EE			
Efficiency Range	Frequency	Percent	Frequency	Percent
≤ 0.49	21	7.14	62	20.13
0.5 – 0.59	34	11.04	77	25.00
0.6 – 0.69	57	18.51	57	18.51
0.7 – 0.79	83	26.95	56	18.18
0.8 – 0.89	70	22.73	32	10.39
≥ 0.9	42	13.64	24	7.79
Total	308	100	308	100
Efficiency scores				
Mean	0.74		0.64	
Minimum	0.33		0.22	
Maximum	1		1	
Std. Dev.	0.14		0.16	

Source: Field Survey, 2022. Std. Dev. = Standard Deviation

From the VRS DEA results obtained, the average allocative efficiency of the Irish Potato farmers was 0.74, with minimum and maximum efficiency scores of 0.33 and 1 respectively, meaning that if these farmers operated at full allocative efficiency, they could lower their production costs by 0.26 percent while producing the same amount of output. The average economic efficiency level is 0.64, with minimum and maximum efficiency scores of 0.22 and 1 respectively. That means a farmer with an average level of economic efficiency may cut the current average production costs by 36 percent to reach the minimum cost level while maintaining the same output level. This also indicates that, Irish potato farmer with a mean level of economic efficiency

would save production cost by 36 percent $[(1 - (0.64/1)) \times 100]$ to reach the level of most economically efficient producer. This study is in consonance with the findings of Gautam *et al.* (2020) which stated that an improvement in water management practices can optimise irrigation efficiency, leading to higher profits for the farmers by with irrigation efficiency score of approximately 37 percent but reveals a lower efficiency scores compared to the efficiency scores reported by Hassan, (2021).

Determinant of efficiency

The estimation results of the bootstrapped truncated regression for the Irish potato farmers are presented in Table 4.

Table 4: Bootstrapped truncated regression analysis

Variable	DEA VRS Assumption					
	Technical Efficiency		Allocative Efficiency		Economic Efficiency	
	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value
Sex	0.0227 (0.0367)	0.536	0.0347 (0.0223)	0.118	-0.0020 (0.0213)	0.926
Age	-0.0049* (0.0028)	0.084	-0.0052 (0.0019)	0.787	-0.0011 (0.0018)	0.552
Education level	-0.0188 (0.0247)	0.445	-0.0097 (0.0133)	0.466	0.0046 (0.0125)	0.711
Household size	0.0153* (0.0080)	0.057	-0.0039 (0.0048)	0.416	0.0031 (0.0045)	0.493
Primary occupation	0.0024 (0.0104)	0.815	-0.0011 (0.0063)	0.856	-0.0046 (0.0050)	0.442
Secondary occupation	0.0017 (0.0134)	0.897	-0.0048 (0.0081)	0.555	-0.0001 (0.0077)	0.987
Farming experience	0.0022 (0.0037)	0.554	0.0028 (0.0025)	0.271	0.0047** (0.0024)	0.046
Quality of planting seed	0.0048 (0.0115)	0.676	-0.0019 (0.0079)	0.807	0.0053 (0.0076)	0.482
Extension contacts	-0.1427*** (0.0387)	0.000	0.0084 (0.0230)	0.714	0.0140 (0.0216)	0.517
Membership of farm group	0.0517 (0.0397)	0.193	-0.0282 (0.0241)	0.242	-0.0145 (0.0227)	0.524
Transportation cost	-5.32e-06** (2.42e-06)	0.028	-3.33e-07 (1.51e-06)	0.825	1.50e-06 (1.41e-06)	0.287
Land acquisition	0.0175 (0.0159)	0.271	-0.0005 (0.0109)	0.961	0.0103 (0.0103)	0.318
Access to credit	-0.4581 (0.0332)	0.168	-0.0215 (0.0216)	0.320	-0.0225 (0.0196)	0.251
Constant	0.9797*** (0.1517)	0.000	0.8127*** (0.0931)	0.000	0.6358*** (0.0878)	0.000
Sigma	0.1503*** (0.0112)	0.000	0.1537*** (0.0083)	0.000	0.1542*** (0.0072)	0.000
Wald chi ² (14)	33.52***		8.21		10.20	
Log likelihood	60.70		163.61		138.46	

Source: Field Survey, 2022.

1. Significant at 10%, 5%, and 1% correspond to *, **, and ***, respectively.
2. The bootstrapped standard errors are shown in parenthesis

The result in Table 4 shows age was only positively and significantly associated with technical efficiency at the 10 percent level. This implies that technical efficiency increases with age of farmers. This result also is in line with the findings of (Jirgi *et al.*, 2015) and Chepng'etich *et al.* (2014) that revealed positive and significant relationship between technical efficiency and age of farmers. Similar result was also obtained by (Mukhtar *et al.*, 2018). In accordance with *a priori* expectation, agricultural extension contact has a positive effect on technical efficiency and was statistically significant at the 1 percent level. This result contradicts the finding of Anang *et al.* (2020) who observed a negative association between extension contact and technical efficiency but on the other hand agreed with the result reported by (Jirgi *et al.* 2015). According to Jirgi *et al.* (2015) farmers

who have access to agricultural extension obtain better skills and knowledge over time from the extension agents. The skills help them to improve on their farm management practices that can enhance efficiency. The result also shows there are a negative relationship between household size and technical efficiency though it is statistically significant at the 10 percent level. This implies that in some rare cases the smaller the household size the better and more efficient the Irish potato farming as compared to popular believe and assumption of farming with larger household size participation usually result to efficient productivity. This result is at variance with *a priori* expectation but consistent with the findings of Anang *et al.* (2020) on smallholder maize production in Northern Ghana. Transportation cost has a positive influence on technical efficiency and was statistically significant at the 5 percent level.

The results in Table 4 further revealed there is a significant negative relationship between farming experience and economic efficiency at 5 percent level, signifying that farming experience do not necessarily translate to improvement in economic efficiency. That is to say, though farming experience as a variable is important but not sufficient in enhancing economic efficiency. This result contradicts the notion that experiences in farming tends to increase farmers' capacity to do better, believing that the higher the farmer's farming experiences the more efficient his productivity level. Also, farmers with more years of farming experience are better placed to acquire the knowledge and skills necessary for choosing appropriate new farm technologies over time, manage the field effectively and allocate the resources wisely.

CONCLUSION AND RECOMMENDATIONS

In agricultural production and policy debates, efficient allocation of resources has become very imperative and has led many agricultural stakeholders to take the issue of evaluating agrarian practices into consideration. Consequently, the best way to improve output is for farmers to minimise input use or assign their resources efficiently. The bootstrap procedure adopted minimised the sample sensitivity due to biased and serially correlated estimates. After correcting for bias, the average technical efficiency score tends to be lower for bias-corrected (bootstrapped) DEA measure than the conventional DEA measures. The regression result revealed that extension contact, age, transportation cost, and household size were the major significant factors influencing technical efficiency of Irish potato farmers while access to credit, household size and extension contact were the variables with significant impact on allocative efficiency. This study has logical implication for understanding and controlling productive efficiency of Irish potato production among farmers in Plateau State, Nigeria. Of course, like many other studies, some work remains to be done. A future study can investigate the impacts of farm and farmer characteristics on technical, allocative and economic efficiency using the double bootstrap DEA approach to improve robustness of the efficiency scores. In that case, the efficiency measures consider differences in the sources from which errors originate. That perspective can attempt to distinguish between errors arising from farmer discretion and errors arising from systematic factors. From the findings, increase in extension contact or more access to extension agents would help in bringing changes in existing cultivation practices, and improve technical and managerial skills of Irish potato farmers. Irish potato farmers should be encouraged to form and actively participate in various farm groups or cooperatives, this will enhance their access to credit,

markets information and sources of inputs which will further improve their production efficiency.

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