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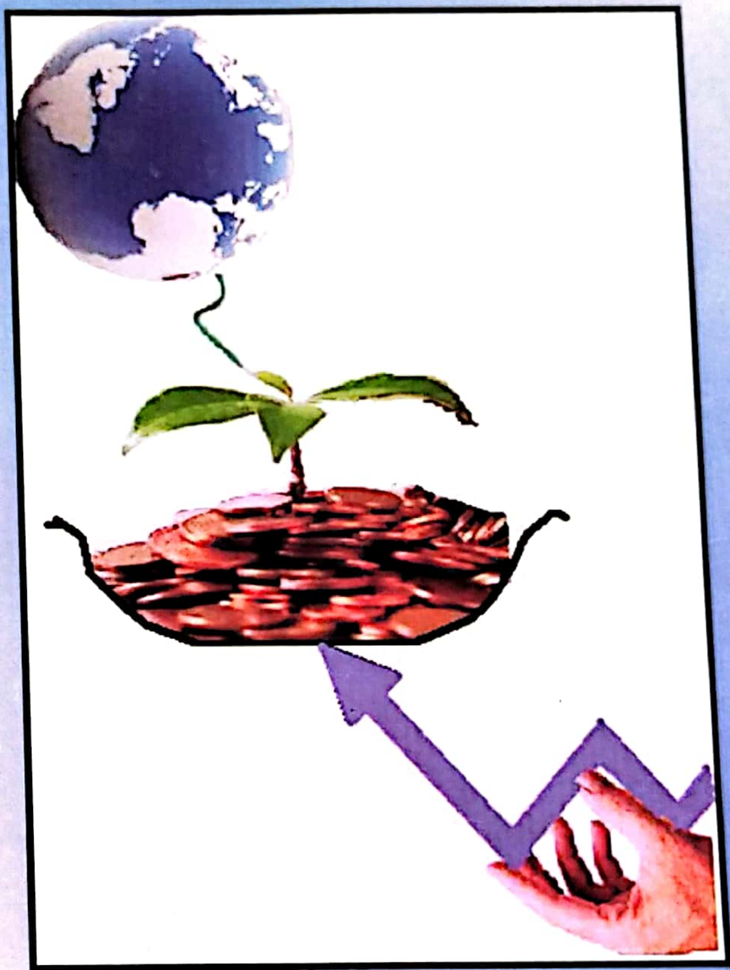

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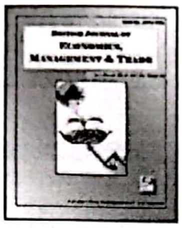

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Technical Efficiency of Millet/Cowpea Farmers in Kebbi State Nigeria: A Double Bootstrapping Approach

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Authors' contributions

This work was carried out in collaboration between all authors. Author AJJ designed the study, wrote the protocol, managed literature searches, data collection and wrote the first draft of the manuscript. Authors HJ and BG managed the data analysis and JNN managed survey and data collection. All authors read and approved the final manuscript.

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ABSTRACT

The research investigated the technical efficiency of farmers in Kebbi State Nigeria, with the aim of generating reliable information on the determinants of efficiency. In order to achieve the objective of the study, Data Envelopment Analysis, Double Bootstrapping procedure within the Principal Component Regression frame work were used. Data for the research was obtained mainly from primary sources through a questionnaire survey of 65 intercroppers who produce a combination of millets and cowpeas. The results from the technical efficiency suggest that there is an opportunity for increasing the technical efficiency levels of millet/cowpea farmers and hence their ability to increase output levels at present input levels and within the existing technology set. Support services such as subsidies on farm inputs, provision of credit and extension services of the new Agricultural Transformation Agenda Programme (ATAP) should be properly implemented and targeted at the small scale farmers.

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Keywords: Technical efficiency; data envelopment analysis; double bootstrapping; principal component regression.

1. INTRODUCTION

For the past 15 years, food crop production growth in Nigeria has been driven completely by increase in area planted rather than by increasing productivity per hectare through innovations and development of high yielding varieties of arable crops (Report of the Vision 2020, [1]). The gap between potential and actual crop yields obtained by farmers suggests abundant opportunity for enhancing productivity. Growth targets thus should be productivity driven Diao, et al. [2] instead of determining productivity by acreage expansion as is the existing practice in Nigeria.

Productivity can be improved if there is reliable empirical knowledge obtainable on technical and allocative efficiency of resource allocation and the factors that determine such efficiencies Jirgi [3]. Most of the farm efficiency studies carried out by Jirgi [4] Baiyegunhi, et al. [5] has shown that resources are inefficiently utilised in the northern parts of Nigeria. Most of the research on efficiency focuses on socio-economic variables such as age, farming experience, extension, education and gender as explanatory variables. The researchers have not examined the influence of risk attitude on efficiency. The fact that risk aversion is associated with the decision making behaviour of an individual, implies that it should be integrated in the determination of factors that influence efficiency Jirgi [3]. Information on risk attitude as a determinant of technical efficiency is lacking in the study area.

Some researchers have explored technical efficiency and its determinants in Nigeria. Empirical studies on the use of the Stochastic Frontier (SF) Model to estimate technical and cost efficiency and their determinants are inadequate in the study area, Tanko and Jirgi [6], Tanko [7]. The two stage Data Envelopment Analysis (DEA) approach to investigate the determinants of efficiency of farmers have been explored byYusuf and Malomo [8], Ajibefun [9]. In the two stage DEA approach, efficiency scores are estimated in the first stage using DEA, and in the second stage, Tobit regression is used to examine the determinants of efficiency. In the second stage Tobit regression is used due to the belief that the dependent variable is censored. However, the appropriateness of the two stage approach have been questioned by Simar and Wilson [10]. The researchers maintained that DEA efficiency scores are serially correlated and biased when used in the two stage DEA approach and that efficiency scores are not censored. Hence, by applying an incorrect approach, the information that was generated by the researchers may not be reliable Jirgi [3].

The objective of the study was to examine the levels of technical efficiency with which the farmers use their production inputs to produce their crops. The levels of technical efficiency will be quantified in order to determine the degree to which the farmers are able to generate the maximum crop yield from the inputs that they have applied. The relationship between the efficiency scores and characteristics of the farmers will be explored so as to have a better insight of the characteristics associated with higher levels of technical efficiency.

2. DATA AND METHODOLOGY

2.1 Data

The study is based on primary data gathered through questionnaire survey of the sampled farmers in the Kebbi State of Nigeria. Kebbi State is located in the north-western part of Nigeria, and is situated between latitudes 11º15' N - 11º35' N, and longitudes 44º7' E- 5º25' E. The State is bordered by Sokoto and Zamfara States to the East, Niger State to the South, Benin Republic to the West and Niger Republic to the North. The population of the State is projected to be 2,209,003,386 and occupies an area of about 36 229 square kilometres. The major cities in the State include Birnin Kebbi (State capital), Argungu, Yauri, Koko, Zuru, Jega etc.

A formal survey was conducted using a structured questionnaire through personal interviews by the researcher and trained enumerators. The questionnaire was administered using a single visit approach. The questionnaire was developed through the consultation of relevant literature to identify the variables to include in the survey. A pilot survey among 10 randomly selected farmers from the study area was conducted to test the questionnaire in terms of the accuracy of the questions to measure the desired aspects. For the purpose of the actual survey a sample of 65 millet/cowpea farmers was randomly selected to

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be included in this research. The survey was carried out in January to February, 2012; Data were collected on production practices for the 2011 cropping season.

2.2 Methodology

The Double Bootstrapping procedure is applied to a truncated regression of non-parametric DEA efficiency estimates on explanatory variables in a two stage procedure explaining the sources of efficiency variations. Following Jordaan [11] the double bootstrap is performed within a principal component regression (PCR) framework to remove all multicollinearity. The following six steps were followed, Jordaan [11].

1) Calculate the DEA output-orientated efficiency score $\hat{\delta}_i$ for each DMU, using the linear programming problem in equation 1.

$$\hat{\delta}_i = \max\{\delta > 0 \mid \hat{\delta}_i\, y_i \le \sum_{i=1}^{n} y_i\lambda;\ x_i \ge \sum_{i=1}^{n} x_i\lambda;\ \lambda \ge 0\} \quad (1)$$

$i = 1 \ldots n$ DMU's

Where y_i is a vector of outputs, x_i is a vector of inputs and λ is a I×1 vector of constants.

The value obtained for $\hat{\delta}$ is the technical efficiency score for the i^th^DMU. It satisfies: $\hat{\delta} \le 1$, with a value of $\hat{\delta} = 1$ indicating that the DMU is technically efficient. This linear programming problem must be solved I times, once for each DMU. A value of $\hat{\delta}$ is thus obtained for each DMU.

2) Use the maximum likelihood method to estimate the truncated regression of $\hat{\delta}_i$ on z_i, to provide an estimate $\hat{\beta}_i$ of β, as well as an estimate $\hat{\sigma}_\varepsilon$ of σ_ε.

The principal components extracted from the original variables that were hypothesised to influence technical efficiency were used as the explanatory or environmental variables (z_i). Following Jordaan [11], the explanatory variables were standardised in order to extract the principal components. For the standardised variables a mean of zero and standard deviation of one was obtained. The Eigen vectors that are used to construct the principal component were calculated using the standardised explanatory variables. Principal components with Eigen vector greater than 1 were included in the regression analysis, Kaiser [12]. The Eigen values of the principal components of the variables that were initially hypothesised to influence the technical efficiency of the monocrop and intercrop farmers are presented in result section.

3) For each DMU $i = 1,\ldots n,$ repeat the next four steps (i - iv) L_1 times to obtain n set of bootstrap estimates B$_i$ $= \{\hat{\delta}_{i,b}^{\,*}\}_{b=1}^{L1}$:

[I]. Draw ε_i from the $N(0, \hat{\sigma}_\varepsilon^{\,2})$ distribution with left truncation at $1 - \hat{\beta} z_i$.

[II]. Compute $\delta_i^* = \hat{\beta} z_i + \varepsilon_i$.

[III]. Construct a pseudo data set (x_i^*, y_i^*), where $x_i^* = x_i$ and $y_i^* = y_i \hat{\delta}_i / \delta_i^*$.

[IV]. Compute a new DEA estimate δ_i^* on the set of pseudo data (x_i^*, y_i^*), i.e.

4) For each DMU, compute the bias corrected estimate $\hat{\hat{\delta}}_i = \hat{\delta}_i - \hat{bias}$, where $\hat{bias}_i$ is the bootstrap estimator of bias obtained as:

$$\hat{bias}_i = \frac{1}{B}\sum_{b=1}^{B} \hat{\delta}_{i,b} - \hat{\delta}_i .$$

5) Use the Maximum likelihood method to estimate the truncated regression of $\hat{\hat{\delta}}_i$ on z_i, providing estimates $\left(\hat{\hat{\beta}}, \hat{\hat{\sigma}}\right)$ of $(\beta, \sigma_\varepsilon)$.

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In the truncated regression, the principal components of the explanatory variables were used as z_i.

6) Repeat the next three steps (i – iii) B_2 times to obtain a set of bootstrap estimates

$$\left\{\left(\hat{\hat{\beta}}_b^*, \hat{\hat{\sigma}}_b^*, b = 1,\ldots,B_2\right)\right\}.$$

[I]. For $i = 1,\ldots n, \varepsilon_i$ is drawn from $N\left(0, \hat{\hat{\sigma}}\right)$ with left truncation at $\left(1 - \hat{\hat{\beta}} z_i\right)$.

[II]. For $i = 1,\ldots,n,$ compute

$$\delta_i^{**} = \hat{\hat{\beta}} z_i + \varepsilon_i.$$

[III]. The Maximum likelihood method is again used to estimate the truncated regression of δ_i^{**} on z_i, providing estimates $\left(\hat{\hat{\beta}}^*, \hat{\hat{\sigma}}^*\right)$.

The results from truncated regression analysis of the bias-corrected technical inefficiency scores on the six principal components with Eigen values greater than one is presented in Table 1.

The result reveals that the variation in the bias-corrected technical inefficiency scores of the millet/cowpea farmers is explained by three statistical significant principal components. Following the procedures discussed by Khaile [13] and Magingxa [14] the coefficients ($\hat{\hat{\beta}}^*$) and standard errors ($\hat{\hat{\sigma}}^*$) from the truncated regression analysis are used to calculate the coefficients of the individual standardised variables that were included in the principal components and the standard errors of the coefficients of the standardised variables.

3. RESULTS AND DICUSSION

3.1 Technical Efficiency of Millet/Cowpea Farmers in Kebbi State

Fig. 1 shows the results of the technical efficiency of millet/cowpea farmers in study area.

The bias-corrected technical efficiency scores of the millet/cowpea farmers range from 0.31 to 1. The average technical efficiency score is 0.86. On average farmers can expand their output by 16.28% ((1/0.86) -1)*100%) if the farmers are to attain technical efficiency of one. This implies that the farmers can increase their output by 16% using the existing inputs better. About 39% of the millet/cowpea farmers have bias-corrected technical efficiency score of 1, which implies that only 39% of the farmers are operating on the production frontier and are said to be technically efficient. The remaining 61% of the farmers are technically inefficient.

3.2 Determinants of Technical Inefficiency of Millet/Cowpea Farmers in the Study Area

Table 2 show the results obtained from the regression analysis of the bias-corrected technical inefficiency scores on the respondents characteristics that were hypothesised to influence technical efficiency of the millet/cowpea farmers. The dependent variable in the regression is the inefficiency index i.e. the reciprocal of the technical efficiency score; hence a negative sign of any of the coefficients means that the variable has a positive influence on the technical efficiency level of the millet/cowpea farmer.

The personal characteristics of the respondents, age and experience have statistically significant positive relationship with the technical efficiency of the millet/cowpea farmers as expected; contrary to *a priori* expectation education has a statistically significant negative association with technical efficiency of the respondents. Specifically, there is a positive statistically significant relationship between age and technical efficiency ($P<0.05$). The result is in line with the findings of Msuya, et al. [15]. Farmer's experience increases with age and resource endowment hence increase in efficiency. In other

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words, older farmers are expected to be more experienced which ultimately aid decision making related to farming enterprise, thus resulting in higher efficiency.

Risk attitude was measured using the experimental approach. For more details see Jirgi [3]. *Fadama* are flood plains and low-lying areas underlined by shallow aquifers found along Nigeria's river system which are used for small scale irrigation.

Contrary to initial expectations education has a negative statistically significant relationship with technical efficiency (P<0.01). The result is consistent with the results reported by Koc, et al. [16]. The probable reason for the inverse relationship between education and technical efficiency could be that the educated millet/cowpea farmers consider farming as a secondary occupation and so they do not give proper attention to farming.

Farming experience has a positive statistically significant association with technical efficiency (P<0.01). The result is as hypothesised. The greater the farming experience the more technically efficient the farmer is, because over time the farmer has acquired farm management and agronomic skills which enhance technical efficiency.

Credit, house type and asset values have negative statistically significant association with technical efficiency of the millet/cowpea farmers. These variables are grouped as wealth generation characteristics. Agricultural credit has a negative statistically significant effect on technical efficiency of the millet/cowpea farmers (P<0.05). The result is opposite from the *a priori* expectation.

Table 1. Scores on the six principal components (ZPC1 to ZPC6) with Eigen values greater than one Kebbi State, January, 2012

Variables	Coefficients	Standard error	z-statistic	Probability (z)
Intercept	-0.886	0.159	-5.550	6.825
ZPC1	-0.044	0.183	-0.241	0.810
ZPC2	-0.364**	0.149	-2.433	0.018
ZPC3	-0.116	0.155	-0.747	0.458
ZPC4	-0.039	0.207	-0.193	0.848
ZPC5	0.358*	0.193	1.849	0.069
ZPC6	0.263*	0.153	1.714	0.091

*** and * represents statistical significance at 5% and 10% probability level respectively.*

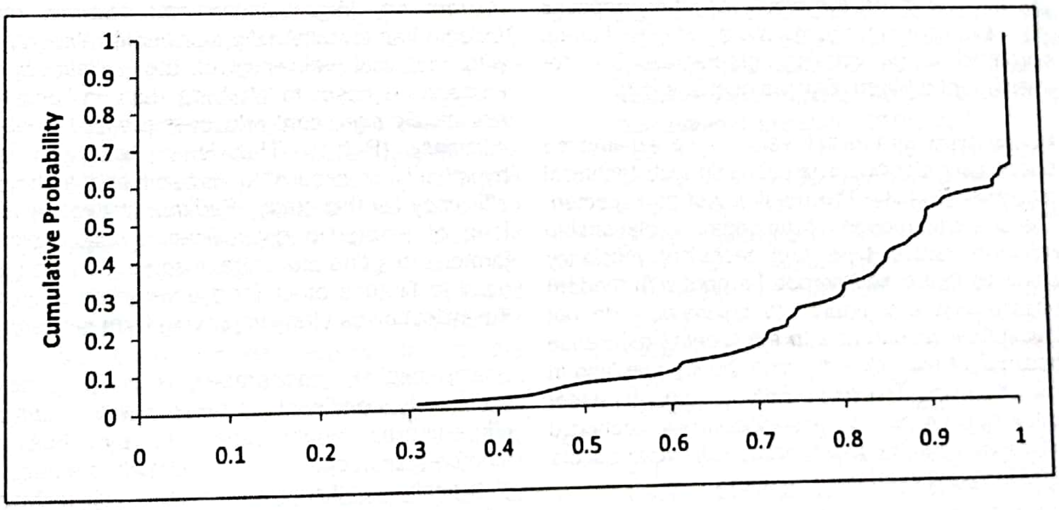

Fig. 1. Cumulative probability distribution of the bias-corrected technical efficiency scores of the millet/cowpea farmers in Kebbi State, January 2012

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Table 2. Results from the truncated regression of the bias-corrected technical inefficiency scores on its determinants for the millet/cowpea farmers, Kebbi State, January, 2012

Variable	Coeff'	Std error	z-stat	Prob (z)
Personal characteristics				
Age	-0.155**	0.068	-2.267	0.028
Education	0.302***	0.095	3.162	0.003
Farming experience	-0.176**	0.066	-2.663	0.011
Risk attitude	-0.086	0.074	-1.157	0.253
Household size	-0.082	0.051	-1.597	0.117
Wealth generation characteristics				
Credit	0.245**	0.109	2.2475	0.029
House type	0.099*	0.053	1.879	0.066
Asset value	0.100*	0.057	1.771	0.083
Traction	0.086	0.052	1.662	0.103
Natural resource capital				
Land fragmentation	-0.068	0.063	-1.085	0.283
Land degradation	-0.041	0.041	-1.019	0.313
Fadama	-0.082*	0.048	-1.732	0.09
Social capital				
Cooperative	-0.070*	0.036	-1.938	0.059
Human capital development				
Extension	-0.243**	0.109	-2.211	0.032
Other characteristics				
Kilometre	0.026	0.045	0.575	0.568
Market	0.069	0.115	0.602	0.55

*Note' The dependent variable is the inefficiency index i.e the reciprocal of the technical efficiency (TE) score; hence a negative sign of the coefficients means that the variable has a positive influence on the TE level of the millet/cowpea farmer. ***, ** and * represents statistical significance at 1%, 5% and 10% prob level respectively*

The result implies that access to agricultural credit decreases technical efficiency of the farmers. Similar result was reported by Baruwa and Oke [17]. The probable reason could be that the farmers divert the credit for other purposes (for example marrying more wives, funeral ceremonies or naming ceremonies or for investment off-farm, Baruwa and Oke [17].

House type and asset value have an inverse statistically significant relationship with technical efficiency (P<0.1). The result is not as expected. The probable reason for the negative relationship between house type and technical efficiency could be that millet/cowpea farmers with modern houses that are thought to be wealthy do not invest their resources into the farming enterprise because of the risk in farming, hence resulting in low efficiency. The most likely reason why asset value has an inverse association with technical efficiency could be that farmers with more assets tend to invest in off-farm business.

The results suggest that the farmers who are thought to be wealthy in the study area do not invest much of their resources in farming hence their wealth have negative influence on efficiency. These farmers are likely to be technically less efficient.

Among the natural resource capital, land degradation, fragmentation and *fadama,* only *fadama* has a statistically significant relationship with technical efficiency of the millet/cowpea farmers. Access to *fadama* has a positive statistically significant relationship with technical efficiency (P<0.1). This is in line with the hypothesis of access to *fadama* and technical efficiency for this study. *Fadama* cultivation is a form of enterprise diversification which allows farmers to generate extra income that can be used to finance other farm enterprises such as the millet/cowpea thus improving farm efficiency.

Social capital (cooperative) has a positive statistically significant relationship with technical efficiency as hypothesised. As hypothesised, membership of cooperative society has a positive statistically significant relationship with technical efficiency (P<0.1). Membership of cooperative society gives farmers better access to loans Oboh and Ekpebu [18], farm inputs and farm management training on how to improve agronomic practices thus improving efficiency.

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Access to agricultural extension as a human capital development variable has a positive statistically significant influence technical efficiency ($P<0.05$). The positive relationship between access to agricultural extension and technical efficiency is in accordance with the initial hypothesis. The result is similar to results reported by Nyagaka, et al. [19]. 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.

4. CONCLUSION

In conclusion, the millet/cowpea intercrop farmers from Kebbi State, Nigeria are relatively technical efficient. However, there still is scope for most of the farmers to expand their production levels at current input levels. The results of the determinants of technical efficiency of the millet/cowpea farmers show that personal characteristics (age, education and experience) influence technical efficiency. There is an indirect association between the wealth generation characteristics of the farmers, specifically, credit, house type and asset value have negative relationship with technical efficiency. This suggests that the millet/cowpea farmers do not invest much of their wealth in farming. The natural resource capital (*fadama* cultivation) has positive relationship with technical efficiency of the farmers. The result implies that an increase in *fadama* cultivation will enhance technical efficiency. Policies geared towards improving wealth generation characteristic and natural resource capital (*fadama*) should be enhanced. Specifically, *fadama* users should be encouraged by providing them with irrigation pumps and improved technology. The results from the technical efficiency suggest that there is a scope for increasing the technical efficiency levels of intercrop farmers and hence their ability to increase output levels at current input levels and within the existing technology set. The results from the study will be disseminated to the farmers through the Agricultural Development Project (ADP) of Kebbi State, Nigeria. The mandate of the ADP is to disseminate information from the research institutes to the farmers by organizing workshops/training and by direct contact between the extension agent and farmers.

Support services such as subsidies on farm inputs, provision of credit and extension services of the new Agricultural Transformation Agenda Programme (ATAP) should be properly implemented and targeted at the small scale farmers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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