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REGULAR ARTICLE

TECHNICAL EFFICIENCY AND IMPACT EVALUATION DIFFERENTIALS BETWEEN THE ADOPTERS AND NON-ADOPTERS OF NERICA IN THE SIX BASELINE STATES IN NIGERIA

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ABSTRACT

The study examined the adoption rate of New Rice for Africa (NERICA), technical efficiency differentials of production of these varieties between adopters and non-adopters and the determinants. It further analysed the impact of adoption of NERICA on area cultivated, output, yield, expenditure and total income of rice farmers in the NERICA baseline states in Nigeria. To achieve the objectives, it employed the descriptive statistics, stochastic production frontier and counterfactual outcomes framework of modern evaluation technique (the Local Average Treatment Effect) to analyse 621 rice farmers across the six NERICA baseline states in Nigeria in 2012. The findings show that NERICA adopters were more technically efficient than the non-adopters. In addition, adoption of NERICA was found to significantly increase the areas of land cultivated, output, yield, household expenditure, per capita household expenditure and total income among NERICA adopters by 1.2ha ($p < 0.01$), 1998.2kg ($p< 0.01$), 191.2kg/ha ($p < 0.1$), N13,222.63≈$66.4 ($p < 0.05$), N2,015.6≈$10.1 ($p < 0.05$) and N145,098.7 ≈$728.0 ($p < 0.01$) respectively despite their high level of inefficiency (39 percent) by the adopters. The positive impact of NERICA adoption on rice yields, poverty status measured by the per capita household expenditure and total farm income of farmers is a clear indication that NERICA has the potential to increase rice productivity, reduce poverty and food insecurity. NERICA adoption rate will rise if more farmers are aware of the varieties in the study. Farmers who had adopted, and government at all levels should therefore intensify their efforts to encourage others rice farmers possibly through the extension agents on the need to grow NERICA varieties so as to increase rice production level, reduce rice importation and ensure a sustainable rice production.

Keywords: Economic benefits, Rice farmers, Counterfactual approach, with and without adoption, Poverty
JEL: C21, C30, D24, E23, O31, O32, O33, P51, Q01, Q16, Q55, R39

INTRODUCTION

Rice has a great economic importance as it serve as a source of income, and a major staple food in most Nigerian homes (**Ologbon *et al.*, 2012**). Rice is an increasingly important staple and strategic grain crop in Nigeria (NCRI, 2004). The country consumes about five million metric tonnes annually but local production has not been able to meet this need over the years. Therefore, the difference between what is consumed and what is produced is provided through importation of about 2.1 million metric tonnes making the country to spend about N356 billion annually. Even though the country has a potential land area for rice production of about 4.6 billion hectares, only 1.7 million hectares (35%) is grown with rice (**Imolehin and Wada, 2000)** indicating that food sufficiency through rice production has not yet been realized (**FRN, 2006**). Availability of improved rice varieties and the adoption by the resource-poor rice farmers is therefore very important to achieve food security. There are many varieties of rice grown in Nigeria. Some are considered as "traditional" varieties, while others were introduced from research institutes or imported from Asia as improved varieties (**Tijani, 2006**). New Rice for Africa (NERICA) varieties development is one of the most significant advances in crop improvement in Africa (**Kinkingninhoun-Medagbe *et al.*, 2014**).

Development of the NERICA varieties began in 1991, when Africa Rice initiated an interspecific breeding program for the upland ecosystem (**Diagne *et al.*, 2010**) and released for use in 1996 (**IFAD 2011**) through Participatory Value Selection (PVS) trials and other extension efforts (**Fowler, 2012**). NERICA is crossed between the two species, *Oryza sativa*, Asian-domesticated rice, and *Oryza glaberrima*, African-domesticated rice. NERICA varieties mature quickly making them to cope with drought and compete with weeds which act as serious constraints in upland rice farming in West Africa. NERICA is harvested more times a year with an average yields of 1,500 kg/hectare without fertilizers and 2,500 kg/hectare using fertilizers, and traditional rice yields of 800 kg/hectare (**AfDB, 2014**). The improved rice varieties got to Nigeria in 1999 through a three-year Participatory Varietal Selection (PVS) trials program in both upland and lowland ecologies (**Tiamiyu, 2008**). It was officially release in 2005 and widely disseminated by the Multinational NERICA Rice Dissemination project from 2006 to 2010. Today, farmers have access to more than 62 varieties of high-yielding rice species produced by research institutes in Nigeria out of which more than eighteen (18) NERICA varieties have been disseminated but most common types grown by farmers are NERICA 1 and NERICA 2. The improved rice varieties were mainly introduced with the main objective to improve rice yield, total farm income and farmers' livelihood when adopted.

This study determined the rate of adoption of NERICA varieties, the technical efficiency and it determinants. In addition, it analysed the impact of adoption of this improved technology on poverty status, area of land cultivated, rice output, rice yield, household expenditure and income of the rice farmers in the study area. Most of the past studies on NERICA in Nigeria (such as: **Dontsop *et al.*, 2011; Awotide *et al.*, 2012; Ojehomon *et al.*, 2012**) only focused on the impact of NERICA adoption or seed vouchers by using either a state or two states without considering the technical efficiency and its determinants between the adopters and non-adopters. This study is unique by investigating the level of adoption, TE efficiency differentials and the impact of adoption on outcomes such as rice yield, per capita expenditure, and income at the NERICA baseline states after some years of its introduction. The only similar study to this as far as we know was that of **Asante *et al.*, (2014)** that estimated the impact of adoption of NERICA on the technical efficiency of smallholder farmers in Ghana using cross sectional data.

The study is imperative because it approaches the problem of estimation of adoption rates and their determinants from the perspective of modern evaluation theory as exposed in the treatment effect estimation literature (**Imbens and Wooldridge, 2009; Imbens, 2004; Wooldridge, 2002; Heckman and Vytlacil 1999; Angrist *et al.*, 1996**). It will contribute to literature on both technical efficiency and impact evaluation in agriculture in developing countries.

DATA AND METHODS

This work is a cross-sectional study of rice farmers in six states where the NERICA varieties were first disseminated at its official release in 2005 conducted in 2012. The states were: Kaduna (located in the North Western Nigeria), Nasarawa (located in the Northcentral Nigeria), Ondo Osun, Ogun and Ekiti States, all in the Southwestern Nigeria. These six states are also currently participating in the Multinational NERICA Dissemination Project.

This study draws adoption and modern impact evaluation methodology from previous studies (such as: **Asante *et al.*, 2014 in Ghana Ojehomon *et al.*, 2012, Awotide *et al.*, 2012, Dontsop 2011 all in Nigeria; Kijima *et al.*, 2011 in Uganda; Diagne *et al.*, 2009a,b; 2006 in Cote D'Ivoire; Diagne *et al.*, 2004 in Guinea; Spencer *et al.*,2006**).

Survey Data

The paper used farm survey data collected through a semi-structured questionnaire and a Focus Group Discussion (FGD) schedule. In each state, one FGD was conducted with selected farmers and their village head (or his representative) across the rice growing communities to obtain prior information on their livelihoods and rice farming system. Members of the group were asked to state the status of the infrastructure in their village, the major livelihood activities in the village, the natural or man-made incentives for rice cultivation in the village, types of rice varieties grown and level of production by varieties, in the village. For each rice variety listed, among the information, the villagers were asked to identify the type of variety, ecology in which the variety is cultivated, when the variety was introduced, if applicable, the person that introduced the variety and the institution where the person comes from, the introduction method used, variety height and cycle. This was followed by questions regarding the characteristics of each variety such as the agronomic and morphological; post-harvest; cooking and organoleptic characteristics of each variety.

The semi-structured questionnaire was administered after the selection of rice farmers in each village. The full list of the village varieties was delivered to each enumerator after the FGD, and each sampled farmer was asked on whether he/she has knowledge of each of the variety listed. If the answer to the question was 'yes', then the farmer was asked whether he or she has cultivated the variety in past five years (2006 to 2011). The knowledge of the variety was defined as a 'yes' answer to the first question and the adoption as the cultivation of the variety. This was followed by questions on the socio-economic and demographic characteristics of each farmer. Data were collected to elicit information on the farmer's socio-economic condition, the farm's characteristics, participation in the new rice variety selection, and experience with NERICA adoption, farm productivity, and income. Data on the type of rice varieties planted, farmer's knowledge and adoption of rice varieties, inputs use, mode of access to seed and their management, production and agricultural income, non-farm income and assets, food intake, children's schooling and health, etc. were also collected.

Sampling procedure

A multi-stage random sampling technique was used to select rice farmers from the six baseline states where NERICA dissemination activities have taken place since 2005 in Nigeria. At a first stage, the six states (Kaduna, Nasarawa, Osun, Ekiti, Ondo and Ogun States) were selected purposively because since the official release of NERICA in 2005, no study as far as we know has evaluated the adoption rate of this variety in all the baseline states in Nigeria nor evaluated technical efficiency of adopters compared to the non-adopters. **Spencer *et al.*,(2006); Dontsop (2011)** for instance, estimated the adoption rate of NERICA in only three out of the six baseline states (**Kaduna and Ekiti by Spencer**

***et a1*., 2006; Osun State by Dontsop, 2011**). It is therefore worthwhile to estimate the adoption rate of NERICA in all the six baseline states and investigate whether farmers who have adopted the improved varieties were technically efficient or not compared to the non-adopters.

In the second stage (due to the difficulties at getting the list of rice-producing farmers in the selected states as a result of lack of rice farmers' census), the lists of all the rice growing Local Government Areas (LGAs) and villages within the LGAs where rice is grown and NERICA seeds have been disseminated were collected from the respective Agricultural Development Programme (ADPs) officers. Two rice producing LGAs were selected per state while the non- rice producing LGAs were not selected. The third stage was a random selection of two villages where NERICA dissemination activities have taken place, known as PVS villages and one non- PVS NERICA village per LGA. That is, for every two NERICA villages selected, one adjacent village (that is within 15 to 20km) where NERICA is yet to be disseminated was also randomly selected as control. The distance was chosen because the closer the non NERICA village is to the NERICA village, the greater the possibility of farmers' knowledge of the variety through other means apart from official means of dissemination. In each state, six villages were selected. The chance of selecting a non-PVS village was based on the selection of a NERICA village within that vicinity.

The fourth stage of sampling involved the random selection of at least a hundred (100) rice farmers in each of the selected states. A total of 621 rice farmers were selected from the list of rice farmers in selected villages based on the availability of rice farmers (Table 1). The sample size on the population size of rice farmers would have been used but this was not available.

Analytical Techniques

In order to address the objectives of this study, both descriptive and econometrics analytical tools (Stochastic Production Frontier (SPF) and Local Average Treatment Effect (LATE)) were employed. Descriptive statistics such as measures of central tendency (mean and standard deviation) as well as frequency distribution tables were used where necessary in order to provide insight into the distribution of socioeconomic and demographic characteristics of farmers in the research sample. Technical efficiency and its determinants of adopters of NERICA and non-adopters were analysed with SPF and Tobit models. The Cobb-Douglas production function provides an adequate representation of the production technology.

Technical Efficiency

The Technical Efficiency (TE) is defined in terms of the ratio of the observed output (Y_i) to the corresponding frontier output (Y^*), conditioned on the level of inputs used by the farm (**Battese and Coelli, 1995; Essilfie *et al.*, 2011**). This is mathematically expressed as (Eq.1).

$$TE = \frac{Y_i}{Y_i^*} \quad (1)$$

Table 1: Distribution of the research sample rice farmers and retrieved questionnaires

State	LGA	Selected villages PVS villages	Non-PVS villages	No. of respondents selected	No. of retrieved questionnaires
Kaduna	Kagarko	Jere (21) Kagarko (21)	Sabo- Iche (17)	59	109
	Igabi	SabongeriGirku (17) Gefe (17)	Wusa (16)	50	
Nasarawa	Lafia	Igibi (17) Mararaba (17)	Assakio (18)	52	104
	Obi	Obi (17) Ikosege (17)	Agwatashi (18)	52	
Ekiti	Gbonyin	Aisegba-Reserve (13) Agbado-Ipole (10)	Agbado (26)	49	103
	Ijero	Ikoro (31) Iroko (14)	Ikoro (9)	54	
Ondo	Akure North	Ayede-Ogbese (10) Araromi (32)	Eleyowo (22)	64	105
	Akure South	Adofure (14) Aule (11)	Aule (16)	41	
Ogun	Obafemi/Owode	Kajola (18) Mokoloki (18)	Mogbara (20)	56	100
	Ewekoro	Obada-Oko (15) Asipa-Ilao (14)	Oluwaji (15)	44	
Osun	Oriade	Akola (17) Erin-Ijesa (16)	Erin-Oke (17)	50	100
	Atakumosa	Maika (17) Aba-Hitila (16)	Oke-Aba (17)	50	
Total					621

Note: Figure in parenthesis represent the number of sampled farmers

Where Y_i is expresssed as (Eq. 2).

$$Y_i = f(X_{ij\,;}\beta_j)\exp(V_i - U_i) \quad (2)$$

For this study the following Cobb-Douglas stochastic frontier production function was specified as (Eq. 3).

$$LnY_i = \beta_0 + \beta_j LnX_{ij} + V_i - U_i \quad (3)$$

Where
Y_i Output (Kg) for the i^{th} farmer
β_0 Constant term
Ln Natural logarithm
β_j Unknown parameters to be estimated
X_{ij} the j^{th} input (j = 1-5) used by i^{th} farmer. X_1 is labour used (person-hours); X_2 is quantity of seed used (kg); X_3 is the quantity of fertilizer used (kg); X_4 is the herbicide used (lire); X_5 is farm size used for rice production (ha)
$V_i - U_i$ Composite error term.
V_i Random error not under the control of the famers, assumed to be independently and identically distributed as N (0, δ_u^2) independent of U_i
U_i Non-negative random variable associated with technical inefficiency (1- TE) effects of production of the farmers involved. This is identically and independently distributed as a truncated normal. The truncations are at zero of the normal distribution (**Battese and Coelli, 1995**)

Tobit regression model
We used Tobit regression model to determine factors affecting the TE inefficiency (U_i) based on **Battese and Coelli (1995)**. The model is specified as (Eq. 4).

$$U_i = \delta_0 + \delta_j Z_{ij} + d_i \quad (4)$$

Where the independent variables are as follows;
Z_1 Sex (male =1, otherwise 0)
Z_2 Age (years)
Z_3 Marital status (1= married, 0 = Divorced)
Z_4 Household size (number)
Z_5 Educational level (years)
Z_6 Years rice farming experience (years)
Z_7 Assets owned (N)
Z_8 Access to credit visits (Access =1; otherwise 0)
Z_9 Access to extension visits (Access =1; otherwise 0)
d_i Error term, independent and identically distributed and obtained by truncation of the normal distribution with zero mean and constant variance (δ^2)
δ_j Unknown parameters to be estimated

Counterfactual estimations
The impact estimates are based on the LATE following **Imbens and Angrist, (1994).** The paper used the Local Average Response Function (LARF) to estimate LATE because the instruments (NERICA knowledge and access to NERICA seed were not randomly distributed in the population). The study assessed the causal effects of NERICA adoption on rice yield total quantity of rice in kg harvested per area planted), output, household expenditure, per capita expenditure and farm total income. To control for differences in socio-demographic and environmental characteristics of adopters and non-adopters, and to enable a causal interpretation of NERICA adoption on the variables of interest, the study used the counterfactual outcome framework to control for such differences.

The counterfactual framework detects two important sources of bias in the estimation of treatment effects These include the initial differences between adopters and non-adopters in the absence of treatment, and the difference between the two groups in the potential effect of the treatment. The parameters of estimation are the ATE which is the expected effect of treatment on a randomly drawn person from the population, the average effect of the treatment on the treated (ATT) which represents the mean effect for those who actually participated in the treatment, and the average effect of treatment on the untreated (ATU) which measures the expected treatment effect for an individual drawn from the population of non-participants. Two alternative statistical independence assumptions were made to identify ATE, ATT and ATU following **Imbens and Wooldrige, (2009); de Janvry *et al.*, (2010)**. The first is the *unconditional independence* assumption: this assumption states that the population distribution is independent of outcome of exposure to treatment. Under this assumption, ATE, ATT and ATU were identified by the mean difference of observed outcomes of adopters and non-adopters. The second assumption is the *conditional independence* assumption also called "selection on observables". The population distribution is independent of the outcome of exposure to treatment conditional on some observed components. Under this assumption the conditional mean treatment effects are all identified by the conditional mean difference of observed outcomes.

By the counterfactual outcome framework a randomly selected rice producing household had two potential outcomes of adopting NERICA varieties. This is specified as (Eq. 5).

$$Y = Y_1\, if\ T = 1\ and\ Y = Y_0\, if\ T = 0 \quad (5)$$

In Eq. 5, Y is the outcome of interest as a result of exposure to treatment which in our study include, rice output, productivity, expenditure, poverty reduction, income. T is the adoption status. For the sample of randomly selected rice producing households the average effect of adoption, which is also known as average treatment effect, ATE, is generally specified as (Eq. 6)

$$ATE = E\,(Y_1 - Y_0) \quad (6)$$

Differences in knowledge and access to information, physical accessibility as well as socioeconomic condition were expected to present unequal opportunities for adoption (**Tambo and Abdoulaye, 2011**). The impact parameter given adoption status, also known as the average treatment effect on the treated, ATT or ATE1, is specified as (Eq. 7).

$$ATT = E\,(Y_1 - Y_0)\,|T = 1) = E(Y_1\,|\,\mathrm{T} = 1) \quad (7)$$

$Y_{1,}Y_0$ Outcome of exposure to treatment, T treatment variable status; (T=1) Exposure to treatment. ATU can be expressed as (Eq. 8).

$$ATU = E\ (Y_1 - Y_0)\ |T = 0) = E\big(Y_1 \,\big|\, \mathrm{T} = 0\big) \quad (8)$$

Where

ATU or ATE0 average treatment effect on the untreated and (T=0) non exposure to treatment

Once a consistent estimate of ATE, ATE1 and the probability of exposure P (T = 1) is obtained, the expected "non-exposure" bias (NEB) is defined as (Eq. 9).

NEB= P(T=1) x ATT ATE (9)

JEA is the joint exposure and adoption parameter and is consistently estimated by the sample average of observed adoption outcome value. This is estimated as (Eq. 10).

$$JEA = \frac{1}{n}\sum_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{y_i} \quad (10)$$

The Population Selection Bias (PSB) is estimated as (Eq. 11).

PSB=ATU-ATE (11)

In this study access to the NERICA varieties was considered the most satisfactory condition for adoption (use of at least one NERICA variety in the specified cropping season). However, it was possible that some farmers had access to the seeds but did not plant the seeds. This implies that some farmers may have complied while others did not. In this case the impact on the farmers who received the seeds and subsequently planted, which is the local average treatment effect "LATE", is a more useful estimate of impact. The non-parametric local average treatment effect (LATE) framework was used to estimate the causal effect of the adoption of NERICA on total farm income, yield, and expenditure. Because the adoption variable is endogenous, the LATE parameter was estimated with the combined variable of awareness and access to seed of a NERICA variety as instrumental variable. With this non-random instrumental variable in the target population, the OLS with interaction local average response function (LARF) was used to estimate the LATE parameter for the impact of NERICA varieties. The LATE parameter is estimated as (Eq.12).

$$LATE = E\ (Y_1 - Y_0)|\ P = 1, T = 1 \quad (12)$$

Poverty level: This was calculated for the adopters and non-adopters using the Foster-Greer-Thorbecke poverty indices (FGT, 1984). The relative poverty line of 2/3 of the mean per capita income was used to generate the aggregate values of the poverty incidence. The FGT index is estimated as (Eq. 13).

$$P_\alpha = \frac{1}{n}\sum_{i=1}^{q}\left(\frac{Z - Y_i}{Z}\right)^{\alpha} \quad (13)$$

where $\alpha \geq 0$ and takes the values of 0, 1 and 2 for poverty incidence, depth and severity respectively; q is the number of people with an income below the poverty line; Y_i is the income represented by the total household expenditures of ith household, n is the total population and Z is the poverty line. The definitions of these indices are given below.

When $\alpha = 0$, then $P_\alpha = P_0$ gives the Incidence of Poverty (or poverty headcount Index). This is the share of the population whose income or consumption is below the poverty line, that is, the share of the population that cannot afford to buy a basic basket of goods. Similarly, for non-monetary indicators the incidence of poverty measures the share of the population that does not reach the defined threshold (for instance, the percentage of the population with less than three years of education).

RESULTS AND DISCUSSION

Adoption Rate of NERICA Varieties

Table 2 showed that the actual adoption rate for all the sampled state to be 57 percent. Across the individual states, the actual adoption rate was 77 percent, 67 percent, 62 percent, 62 percent, 47 percent and 8percent in Ondo, Ekiti, Nasarawa, Ogun, Kaduna and Osun States respectively. This rate is too low but is in agreement with the finding of **Ajewole, *et al.*, (2015).** The potential adoption rate (ATE), which represents the true demand for NERICA varieties by the target population was estimated to be 80 percent for the study area. Specifically, 98 percent, 90 percent, 86 percent, 84 percent, 82 percent and 13 percent in Nasarawa, Ondo, Ekiti, Ogun, Kaduna, and Osun States respectively. This suggest that if the whole population was aware of, and have access to NERICA seed before the survey, the NERICA adoption rate in the study area could have been 80 percent instead of the actual 57 percent. Thus, for entire study area (six states), the estimate of the population adoption gap was accordingly 23 percent, and statistically significant at 1 percent level. The corresponding estimates of the population adoption gap (that is, the non-awareness bias) for Nasarawa, Kaduna, Ogun, Ekiti, Ondo, and Osun States are 36 percent, 35 percent, 22 percent, 19 percent, 14 percent, and 5 percent respectively, and all are statistically significant at 1 percent level. At the time of this study, the adoption rates among the NERICA exposed subpopulation (ATE1) in the study area was 81 percent while in Nasarawa, Ondo, Ekiti,Ogun, Kaduna, and Osun States, the adoption rate were estimated to be 98 percent, 90 percent, 86 percent, 85 percent, 83 percent and 12 percent respectively.

Table 2: Estimation of Population Adoption Incidence Rates

Variables	Ekiti	Kaduna	Nassarawa	Ogun	Ondo	Osun	Pooled sample
ATE	0.859*** (0.038)	0.815*** (0.041)	0.980*** (0.017)	0.839*** (0.043)	0.904*** (0.031)	0.132*** (0.034)	0.799*** (0.017)
ATE1	0.859*** (0.038)	0.834*** (0.041)	0.983*** (0.015)	0.852*** (0.039)	0.904*** (0.031)	0.120*** (0.031)	0.810*** (0.015)
ATE0	0.860*** (0.042)	0.790*** (0.063)	0.976*** (0.021)	0.806*** (0.058)	0.908*** (0.034)	0.157*** (0.051)	0.775*** (0.025)
JAA	0.667*** (0.029)	0.467*** (0.023)	0.624*** (0.010)	0.622*** (0.029)	0.766*** (0.026)	0.084*** (0.022)	0.569*** (0.011)
GAP	-0.192*** (0.009)	-0.348*** (0.028)	-0.356*** (0.008)	-0.218*** (0.016)	-0.138*** (0.005)	-0.048*** (0.015)	-0.230***(0.007)
PSB	-0.000 (0.004)	0.019 (0.018)	0.003 (0.004)	0.012 (0.009)	-0.001 (0.002)	-0.012 (0.011)	0.010* (0.005)
Observed							
NE/N	0.777*** (0.412)	0.560*** (0.048)	0.635*** (0.047)	0.730*** (0.045)	0.848*** (0.035)	0.700*** (0.046)	0.703*** (0.020)
NA/N	0.631*** (0.048)	0.468*** (0.048)	0.644*** (0.048)	0.620*** (0.0488)	0.762*** (0.042)	0.060*** (0.024)	0.569*** (0.021)
NA/NE	0.813*** (0.062)	0.836*** (0.086)	0.985*** (0.076)	0.849*** (0.067)	0.899*** (0.049)	0.086*** (0.034)	0.809*** (0.030)
N	103	109	101	100	105	100	552
NE	80	61	66	73	89	70	388
NA	65	51	65	62	80	6	314

Note: Figures in parentheses are standard errors.
ATE = Population potential adoption rate; ATE 1 = Adoption rate among exposed and access to seed; ATE0 = Adoption rate among non-exposed; JAA = Actual adoption rate; GAP = JAA – ATE ; PBS = Population selection bias ; N = number observed
NE = number of exposed; NA = number of adopters
*** = $p < 0.01$ ** = $p < 0.05$ * = $p < 0.10$

Technical Efficiency

The mean technical efficiency of adopters of New Rice for Africa (NERICA) and non-adopters were 61% and 52% respectively (Table 5). The mean technical efficiency of adopter is higher than 57% reported by Ayinde *et al.*, (2009) in Nigeria and lower than the mean TE of 63%, 65% of improved rice varieties reported by **Okoruwa and Ogundele (2004), Tiamiyu *et al.*, (2010)** across four major rice producing states (Kaduna, Niger, Ebonyi and Ekiti) in Nigeria and in the savannah zone of Nigeria respectively. The mean TE from this study implied that those that adopted NERICA were only able to obtain 61% output of the maximum attainable with given input levels while the non-adopters have 52% optimal outputs from a given mix of production inputs. It was also observed that about 39% and 38% of the sampled farmers who were adopters and non-adopters of NERICA respectively operate below the mean efficiency score of 0.61 and 51%. This variation was confirmed by the value of gamma (γ) which was 0.54 for adopters and 0.83 for the non-adopters suggesting that 54% and 83% variation in output by adopters and non-adopters was respectively due to the differences in technical efficiencies of farm household. The output of rice by NERICA adopters was found to be significantly influenced by labour used, quantity of seed, quantity of fertilizer and farm size. This indicates that as each of these variables are increased, ceteris paribus rice output of NERICA adopters increases. Labour was probably significant because rice production is the most labour intensive activity when compared to other cereals. The positive coefficient and significant of farm size at 1% level by adopters and non-adopters implied that an increase in the size of the farm by a hectare increased farm technical efficiency by 0.4% (Tables 3 and 4).

Determinants of Technical inefficiency

Results in Table 6 shows that differences in TE between adopters and non-adopters exist in the NERICA baseline states in Nigeria**.** Tables 7 and 8 show the results of the inefficiency model in of rice production by NERICA adopters and non-adopters respectively in the study areas. Rice production by adopters of NERICA was observed to be positively and significantly affected by the sex of the rice farmers, age, marital status, household size, years of education and extension visits while the significant factors affecting non-adopters were: the sex, marital status, household size, assets owned and extension visits (Table 8). The positive sign of the parameters in the results means that the associated variable has a negative effect on technical efficiency. The coefficient of sex was estimated to be negative as expected and statistically significant ($p<0.01$) in production of rice by the adopters and non-adopters. The implication is that female rice farmers tend to be more efficient in rice production. Similarly, the positive sign of the parameter of this variable marital status both for the adopters and non-adopters showed that marriage increases inefficiency and make rice farmers less technically efficient than the single. The coefficient of the age of adopters estimated to be positive and statistically significant ($p<0.05$) revealed that that older farmers who adopt NERICA tend to be less efficient in rice production. This might be as a results of their long traditional believe in the cultivation of the traditional rice varieties. Contrary to the a priori expectation, access to extension visit has a positive coefficient to farmers' inefficiency. This implied that increasing access to extension visits will statistically and significantly reduce efficiency of the farmers (NERICA adopters and non-adopters).

Impact of NERICA adoption on rice farm household poverty status

Table 9 showed that 53 percent of rice farmers in the research sample are non-poor. As depicted in Table 10, the incidence (head count), depth and severity of poverty are 0.4670, 0.1591 and 0.0790 respectively. A comparative analysis of NERICA adopters and non-adopters in Table 11 shows that the poverty incidence, depth and severity are lower by 28 percent, 17 percent and 26 percent respectively among NERICA adopters. It is thus apparent that the incidence, depth, and severity of poverty are less among the adopters than the non-adopters in the study area.

Table 3: Maximum likelihood estimates of stochastic frontier for adopters

Variables	Coefficient	Standard Error	t-ratio	p>|z|
Ln labour used	0.1586 ***	0.0185	8.5900	0.0000
Ln seeds used	0.2037 ***	0.0548	3.7200	0.0000
Ln fertilizer	0.0640 ***	0.0204	3.1400	0.0020
Ln herbicide used	-0.0074	0.0365	-0.2000	0.8390
Ln farm size used	0.3550 ***	0.0766	4.6400	0.0000
Constant	6.0988 ***	0.2656	22.9600	0.0000
Sigma_(δv)	0.6157	0.0413	0.5399	
Sigma_(δu)	0.6718	0.0679	0.5510	
Sigma_δ^2	0.8304	0.0818	0.6701	
Lambda (λ)	1.0911	0.0942	0.9065	
Gamma (γ)	0.5435			
Log likelihood function	-453.4523***	0.0000		

Note: *** Significance at $p<0.01$

Table 4: Maximum likelihood estimates of stochastic frontier for non-adopters

Variables	Coefficient	Standard Error	t-ratio	p>|z|
Ln labour used	0.1086***	0.0310	3.5100	0.0000
Ln seed used	0.3399***	0.0759	4.4800	0.0000
Ln fertilizer	0.0290	0.0254	1.1400	0.2530
Ln herbicide used	0.0584	0.0544	1.0700	0.2830
Ln farm size used	0.4209***	0.1033	4.0800	0.0000
Constant	5.8397***	0.4318	13.5200	0.0000
Sigma_(δv)	0.4224	0.0618	0.3171	
Sigma_(δu)	0.9175	0.1057	0.7320	
Sigma_δ^2	1.0202	0.1770	0.6734	
Lambda (λ)	2.1719*	0.1443	1.8891	
Gamma (γ)	0.8251			
Log likelihood function	-206.5447***	0.0000		

Note: *** Significant at p<0.01

Table 5: Frequencies distribution of TE among adopters and non-adopters

	Adopters		Non-Adopters	
Level of Frequency	Frequency	Percentage	Frequency	Percentage
< 0.50	73	20.7	61	38.1
0.51- 0.55	32	9.1	12	7.5
0.56 - 0.60	33	9.4	12	7.5
0.61- 0.65	52	14.8	17	10.6
0.66 - 0.70	51	14.5	16	10.0
0.71- 0.75	49	13.9	12	7.5
0.76 - 0.80	42	11.9	15	9.4
0.81- 0.85	16	4.5	12	7.5
0.86 - 0.90	4	1.1	3	1.9
0.91-0.95	-	-	-	-
0.96 -1.00	-	-	-	-
Mean TE	0.6064		0.5285	
Std. Deviation	0.1674		0.2335	
Minimum TE	0.0014		0.0024	
Maximum TE	0.8755		0.8715	

Source: Computed from MLE Results

Table 6: Test of Hypothesis

Variable	Obs	Mean TE	Difference TE	Std. Dev.	t-value
Adopters	352	0.6064	0.0182***	0.1674	4.2849
Non adopters	160	0.5285		0.2335	

Table 7: Determinants of technical inefficiency of adopters of NERICA

Variables	Coefficient	Standard Error	t-ratio
Sex (Z_1)	4.6128***	1.6931	2.7244
Age(Z_2)	0.1244**	0.0559	2.2236
Marital status (Z_3)	4.6586*	2.5693	1.8132
Household size (Z_4)	0.2207*	0.1218	1.8124
Year of education(Z_5)	0.3267**	0.1345	2.4295
Years of rice farming experience (Z_6)	0.0324	0.0270	1.2009
Assets owned (Z_7)	-0.0742	0.7624	- 0.0973
Access to credit((Z_8)	0.3955	0.8465	0.4672
Access to extension visit((Z_9)	5.0444**	2.5611	1.9696
Access to information on NERICA(Z_{10})	-0.5411	0.8166	- 0.6626
Constant	- 23.8259	10.7392	- 2.2186

Note: ***Significant at p<0.01, ** Significant at p< 0.05, *** Significant at p< 0.10.

Table 8: Determinants of technical inefficiency of non-adopters of NERICA

Variables	Coefficient	Standard Error	t-ratio
Sex (Z_1)	2.2768***	1.1136	2.0445
Age(Z_2)	0.0009	0.0309	0.0281
Marital status (Z_3)	4.1046*	2.1818	1.8813
Household size (Z_4)	0.5391***	0.1960	2.7507
Year of education(Z_5)	-0.0105	0.0581	-0.1808
Years of rice farming experience (Z_6)	-0.0141	0.0331	-0.4249
Asset owned (Z_7)	2.0578**	0.9414	2.1860
Access to credit((Z_8)	-0.4869	0.8040	-0.6056
Access to extension visits((Z_9)	3.1385*	1.8537	1.6931
Access to information on NERICA(Z_{10})	1.6440	1.0724	1.5331
Constant	-7.5723	5.0179	-1.5091

***Significant at p<0.01, ** Significant at p< 0.05, *** Significant at p< 0.10

Table 9: Distribution of respondents by poverty status

Poverty status	Frequency	Percentage
Non-poor	331	53.30
Poor	290	46.70
Total	621	100.00

Table 10: Poverty profile of rice farmers by states in the study area

States	Head count (P_0)	Poverty depth (P_1)	Poverty severity (P_2)
Ekiti	0.3786 (0.0506)	0.1309 (0.0229)	0.0611 (0.0143)
Kaduna	0.4312 (0.05170	0.1218 (0.0189)	0.0468 (0.0102)
Nassarawa	0.4712 (0.0501)	0.2313 (0.0350)	0.1489 (0.0313)
Ogun	0.7100(0.0507)	0.2662 (0.02613)	0.1220 (0.0179)
Ondo	0.2381 (0.0435)	0.0769 (0.0190)	0.0393 (0.0152)
Osun	0.5900 (0.0529)	0.1330 (0.0220)	0.0581 (0.0176)
Pooled sample (Nigeria)	0.4670 (0.0238)	0.1591 (0.0139)	0.0790 (0.0111)

Note: Figures in parentheses are standard deviations

Table 11: Poverty profile of NERICA adopters and non-adopters

Group	Head count (P_0)	Poverty depth (P_1)	Poverty severity (P_2)
Non-Adopters (n=289)	0.5294 (0.0329)	0.17156 (0.0179)	0.0873 (0.0145)
Adopters (n= 332)	0.4134 (0.0299)	0.1466 (0.0157)	0.0693 (0.0112)
Percentage change	28.1	17.0	26

Note: Figures in parentheses are standard deviations

Table 12: Observed sample mean outcomes and differences

Variables	Area cultivated (ha)	Rice output (Kg)	Yield (kg/ha)	Household expenditures (N)	Per capita expenditure (N /person)	Total income (N)
Diffmo	1.1459***	1998.1850***	191.2394*	13222.63**	2015.5850**	145098.7000***
	(0.1666)	(314.6898)	(99.1622)	(5667.4740)	(897.6829)	(22449.9900)
mo_N1	2.6029***	4339.8080***	1412***	76864***	11723.92***	362640.3000***
	(0.1284)	(249.6200)	(69.5949)	(3975.9550)	(675.5535)	(17076.2500)
m0_N0	1.4589***	2341.623***	1220.99***	63641.9300***	9708.334***	217541.6000***
	(0.1061)	(191.6234)	(70.6378)	(4038.8180)	(591.1532)	(14574.0000)
N	606	488	618	616	604	608
N1	323	260	329	327	321	322

Note: *** = p < 0.01 ** = p < 0.05 * = p < 0.10
Robust standard errors in parenthesis, $1 = N199.00
Diffmo mean difference, mo_N1 adopters, N number observed, m0_N0 non-adopters, N1 = Number of treated

Impact of the adoption of NERICA varieties on area of land cultivated, rice output, yield, household expenditure, per capita expenditure and total farm income

Table 12 shows that the adoption of NERICA had significantly increased the areas of land cultivated, rice output, yield, household expenditure, per capita expenditure and total income among NERICA adopters by 1.2ha (p < 0.01), 1998.2kg (p < 0.01), 191.2kg/ha (p < 0.1), N13,222.6 (equivalent to $66.3) (p < 0.05), N2015.59 (equivalent to $10.1) (p < 0.05) and N145098.7 (equivalent to $728.0) (p < 0.01) respectively. The significance increase in farm size cultivated between the NERICA adopters and non-adopter was in line with the findings of **Diagne *et al.*, (2009a)** in a similar study in Benin Republic and **Mendola (2007**) in Bangladesh. The two different studies found a significant increase in farm size between technology adopters and non-adopters with the adopters cultivating larger farm area. The estimated sample mean yield of 1.4 tonnes per hectare by NERICA adopters in the research sample is higher than the average yield of 0.995 tonnes per hectare for upland varieties reported by **Dalton and Guei (2003)** from a sample of 50 farmers from some of the PVS villages in the forest zone of Cote d'Ivoire; 1.2 tonnes per hectare obtained from a similar study by **Diagne (2006)** in Cote d'Ivoire, 0.18 tonnes per hectare from the sampled of 489 rice farmers from three districts-Ejura-Sekyedumase, Hohoe and Tolon-Kumbungu in Ghana (**Wiredu *et al.*, 2010**), but lower than the average yield of 1.5 tonnes per hectare of upland rice yield in two states (Kaduna and Ekiti) of Nigeria by **Spencer *et al.*, (2006);** 2.3 tonnes per hectare for NERICA varieties estimated by **Kijima *et al.*,(2006)** based on a sample of 254 NERICA farmers in Uganda. The additional yield gain of 0.19 tonnes per hectare was also found to be higher than that of 0.14 tonnes per hectare achieved by rice farmers adopting NERICA varieties in Gambia (**Dibba, 2010**). Similarly, adoption of NERICA rice had improved the income of rice farmers in the research sample. The LATE estimates in Tables 6 indicate a significantly increased household per capita expenditure of N2,519.2 ($12.6 at N199 official exchange rate to dollar) or NERICA adopters. This is however lower than N28,739.7 ($144.2) reported by **Ojehomon *et al.*,(2012)** study on the impact of adoption of New Rice for Africa (NERICA) on farmer yield, income and expenditure in Nigeria in 2010.

The results of the disaggregation impact of adoption by the poverty status in Table 13 implied that NERICA adoption positively and significantly (at P<0.01) increased the farm size of the poor adopters by 1.2ha and that of the non-poor adopters by 0.8ha. Rice output has also significantly increased for poor adopters by 1993.9kg/ha, and among non-poor adopter by 1002.9kg/ha (at P<0.1). Also observed was a significant (at P<0.01) impact of NERICA adoption on total income. The total income of rice farmers significantly and positively increased by N169,247.7 ($849.2/ha among the poor adopters and by N106,7($5.4) /ha among the non-poor adopters. Contrary to our expectation, there was no significant difference between the yields and the per capita expenditures of the poor adopters and non- adopters.

CONCLUSION AND RECOMMENDATIONS

This study evaluated the adoption rate of NERICA varieties in the study areas; the technical efficiency of NERICA adopters and non-adopters; and the impact of adoption of the varieties on total farm income, area of rice cultivated, rice yield, per capita expenditure and poverty status of rice farmers. The key findings from the study, the policy implications and recommendations are:

The average farm size of NERICA varieties adopters increased from 1.4 to 2.6ha. This shows that in spite of evident of adoption of NERICA varieties, rice production in Nigeria is still at the small scale level;

The actual adoption rate of NERICA varieties was 57 percent, while the potential adoption rate (ATE) was estimated to be 80 percent in the study area. This suggests that 80 percent of rice farmers would have adopted NERICA varieties if they are fully aware instead of the actual 57 percent. NERICA population adoption gap of 23percent indicates a very high unmet demand for NERICA in Nigeria. It also suggests that there is still a potential to significantly increase NERICA adoption rates in Nigeria.

Table 13: Differential impact of NERICA adoption on area of land cultivated, rice output, household expenditure, per capita income and total income by poverty status using the LATE Estimation

	Area harvested		Rice Output		Yield		Household Expenditure		Per Capita Expenditure		Total Income	
	Poor	Non-poor	Poor	Non-poor	Poor	Non-poor	Poor	Non-poor	Poor	Non-poor	Poor	Non-poor
LARF / LATE	0.55 (0.29)	0.59 (0.30)	1190.10*** (4.06)	1310.34*** (14.22)	-29.29*** (0.16)	-27.12*** (0.00)	11149.87*** (176.45)	13105.52*** (253.48)	1179.46*** (5.59)	1113.34*** (0.25)	69664.12*** (334.53)	65737.06*** (15.07)
Diffmo	1.06*** (0.22)	0.85*** (0.25)	1993.91*** (336.96)	1002.88* (540.54)	214.42 (123.08)	-151.25 (156.20)	1991.73 (2518.29)	3697.94 (9857.69)	-292.46 (194.45)	-2.62 (1446.65)	169247.70*** (33666.2)	106729*** (30779.98)
mo_N1	2.51*** (0.18)	2.53*** (0.18)	3726.18*** (294.33)	4548.40*** (366.71)	1796.83*** (85.01)	1887.44*** (108.55)	40974.74*** (1899.48)	99372.75*** (5957.64)	4614.64*** (129.28)	15987.72*** (906.96)	373747*** (27210.63)	347618*** (22155.16)
m0_N0	1.44*** (0.13)	1.68*** (0.18)	1732.26*** (164.06)	3545.52*** (397.12)	1582.41*** (89.00)	2038.69*** (112.32)	38983.02*** (1653.40)	95674.82*** (7853.70)	4907.10*** (145.25)	15990.34*** (1127.03)	204499.3*** (19824.1)	240889*** (21367.18)
N	245	294	217	217	191	213	248	301	244	303	242	299
N1	126	175	112	127	106	129	129	177	130	180	128	180
Nz1	175	217	155	153	144	149	178	222	180	222	178	221

Note: Figures in parentheses are standard errors. *** = p < 0.01** = p < 0.05 * = p < 0.10
Diffmo mean difference; N number observed; mo_N1 = adopters; N1 Number of treated; m0_N0 = non-adopters; Nz1 Number obs with inst=1; LARF Local Average Response Function

The estimated Population Selection Bias (PSB) of 1.04 percent for those who are aware of NERICA which was statistically significant at 10 percent level among the sub-population of farmers implies that the probability of adoption by a farmer belonging to the sub-population who are aware of NERICA is significantly different from other farmers randomly selected from the general population. The positive sign on the PSB indicates that the farmers who are aware of NERICA varieties are significantly more likely to adopt at least one NERICA varieties than any farmer randomly selected from the population. There is therefore the need to create more awareness of NERICA varieties among the rice growing communities in order to increase the adoption of these improved varieties.

In addition, we found that NERICA adopters were more technically efficient than the non-adopters with certain levels of inefficiencies still existing in both cases (those who have adopted and those who had not) in the selected states. Based on our finding, increase in labour use, quantity of seed, fertilizer and farm size are capable at increasing the technical efficiency of NERCA varieties. Adoption of NERICA significantly (at 1percent level) increased the area of land cultivated, farm output, yield, household expenditure, per capita expenditure and total farm income. This suggests that adoption of NERICA varieties has great potential for poverty reduction and improved livelihood of rice farmers in Nigeria.

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