CHAPTER 7

AN INTEGRATED INPUT DISTANCE MODEL FOR EFFICIENCY AND POLICY ANALYSIS

7.1 Introduction

Majority of efficiency studies in agriculture have adopted one of several approaches available for efficiency analysis. Reducing error in the calculation of efficiency scores of farm households is very important and necessary for effective agricultural policy making. Most studies have attempted to achieve this goal by comparing various methods of measuring efficiency and subsequently the correlation between these models has been calculated. In spite of this, none of these studies with exception of Alene et al. (2006) provided any method for calculating final efficiency score and rank of the farmers. However, Alene et al. (2006) was limited to obtaining final technical efficiency scores using geometric mean (GM) with neither consideration of overall efficiency and determinants nor the weight of each indicator in the final index. Therefore, the focus of this chapter is to provide final technical, allocative and cost efficiency scores of farm households and analyse impact of some policy variables on these efficiency measures in an integrated approach. The principal component analysis (PCA) is employed in assigning weights to the different indicators in order to compute the final efficiency scores. To the best of our knowledge, this study is the first to explore the possibility of integrating farmer's efficiency scores generated from different approaches into a single index using the PCA methodology. In the next section (two), the PCA method of integration is discussed. In section three, results of efficiency scores from the PCA techniques are presented. The results of determinants of technical, allocative and cost efficiency generated by the integrated model are also reported in section three. The last section concludes on the chapter

7.2 The Integrated Model

The principal component analysis (PCA) is used for integrating efficiency indexes. It is a widely used non-parametric method of extracting relevant information from confusing data sets. It is used to reduce the number of variables under study. The PCA technique has been applied in a number of studies both within and outside agriculture (Zhu, 1998; Azadeh and Jalal, 2001; Azadeh and Ghaderi, 2005; Azadeh et al., 2009; Essa and Nieuwoudt, 2003; Jollans et al., 2004). However, no study in agriculture has extended the PCA for obtaining efficiency index.

The goal of PCA is to decompose a data table with correlated measurements into a new set of uncorrelated variables called principal components. Each principal component is calculated as a linear combination of the standardized values of the original variables used for the definition of the index. The weight given to each of these variables corresponds to its statistical correlation with the latent dimension that the index attempts to measure. The number of principal components to retrieve depends on the correlation of the initial variables. If they are strongly correlated with each other, one factor will be sufficient to explain most of their variance. However, if the correlation is weak, several factors will be required in order to explain a significant percentage of their variance. In this case, one will get a set of intermediate indicators, as many as there were common factors, and the final index will be calculated as their weighted sum. The importance of each factor is given by the proportion of the total variance explained. The first new variable y1 accounts for the maximum variances in the sample data and so on. PCA is performed by identifying the eigen structure of the covariance or singular value decomposition of the original data. This would eventually lead to scoring and rankings of units of interest.

For this study, it is assumed there are three variables (indicators) and 240 farm households. Suppose $X = (x_1,\ldots x_3)_{240x3}$ is a 240 x 3 matrix composed by $x_{ij}'s$ defined as the value of the *j*th index for the *i*th farm household, therefore, $x_m = (x_{1m},\ldots x_{240m})^T\ (m = 1,\ldots,3)$. Again, suppose $\hat{X} = (\hat{x}_1,\ldots \hat{x}_3)_{240x3}$ is the standardized matrix of $X = (x_1,\ldots x_3)_{240x3}$ with $\hat{x}_{ij}'s$ defined as the value of the *j*th standardized index for the *i*th farm household and therefore $\hat{x}_m = (\hat{x}_{1m},\ldots \hat{x}_{240m})^T$. PCA is performed to identify new independent variables or principal components (defined as Y_j for j= 1,…, 3), which are, respectively, different linear combination of $\hat{x}_1,\ldots \hat{x}_3$. This is achieved by identifying the eigen structure of the covariance of the original data. The principal component is defined by 240 x 3 matrix $Y = (y_1,..., y_3)_{240x3}$ composed by $y_{ij}'s$ shown by:

$$y_1 = l_{11}\hat{x}_1 + l_{12}\hat{x}_2 + l_{13}\hat{x}_3$$
$$y_2 = l_{21}\hat{x}_1 + l_{22}\hat{x}_2 + l_{23}\hat{x}_3$$
$$y_3 = l_{31}\hat{x}_1 + l_{32}\hat{x}_2 + l_{33}\hat{x}_3 \quad (7.1)$$

where l_{mj} is the coefficient of *j*th variable for the *m*th principal component. $l_{mj}'s$ are estimated such that the following conditions are satisfied:

1. y_1 accounts for the maximum variance in the data, y_2 accounts for the maximum variance that has not been accounted for by y_1, and so on.

2. $l_{m1}{}^2 + l_{m2}{}^2 + l_{m3}{}^2 = 1, \qquad m = 1,...,3 \quad (7.2)$
3. $l_{m1}.l_{n1} + l_{m2}.l_{n2} + l_{m2}.l_{n2} = 0$ for all $m \neq n \quad n = 1,...,3 \quad (7.3)$

The eigenvectors $(l_{m1},...,l_{m3})$ $(m = 1,...,3)$ are calculated and the components in eigenvectors are respectively the coefficients in each corresponding principal component, Y_i:

$$Y_m = \sum_{j=1}^{3} l_{mj}\hat{x}_{ij} \text{ for } m = 1,...,3 \text{ and } i = 1,...,240 \quad (7.4)$$

where $\hat{x}_{ij}$ are the values of the standardized indexes for the farm households.
The weights and PCA scores are estimated as follows:

$$w_j = \lambda_j / \sum_{j=1}^{3} \lambda_j = \lambda_j / 3, \qquad j = 1,...,3 \quad (7.5)$$

$$z_i = \sum_{j=1}^{3} w_j Y_j, \qquad i = 1,...,240 \quad (7.6)$$

where w_j is the share of eigenvalue *j*th in the population variance , Y_j is the value of the principal component *j*th and z_i is the PCA score. The ranking of the farm households is done on the basis of Z_i and therefore it is important to recognize the elements of Z_i so as to explore and analyze the impact of each indicator in determining the rank of each farm household. Since Z_i is obtained from equation (7.6) and Y_j is computed from equation (7.4), following Azadeh et al. (2009), it can be proved that

$$Z_i = \sum_{j=1}^{3} w_j Y_j = \sum_{j=1}^{3} w_j \left(\sum_{j=1}^{3} l_{mj} \hat{x}_{ij} \right)$$

$$= \sum_{j=1}^{3} \sum_{j=1}^{3} w_j \left(l_{mj} \hat{x}_{ij} \right) = \sum_{j=1}^{3} \hat{x}_{ij} \left(\sum_{j=1}^{3} w_j l_{mj} \right) = \sum_{j=1}^{3} \hat{x}_{ij} \hat{w}_m \tag{7.7}$$

where $\hat{w}_m = \sum_{j=1}^{3} w_j l_{mj}$, $m = 1,...,3$.

The value of $\hat{w}_j$ for each indicator shows the importance of that indicator in overall ranking of farm households. That means, a high value of an indicator $\hat{w}_j$ has positive impact on the value of Z_i. To calculate efficiency score related to each farm household, the values of $\hat{w}_j$'s are transformed such that they are bounded between zero and one. This is done so that these values demonstrate the difference of indicators importance. To achieve this, each of the values of $\hat{w}_j$ is divided by the sum of the value of indicators importance. The final efficiency score of *i*th farm household is calculated as follows:

$$\varphi_i = \sum_{j=1}^{3} x_{ij} \tilde{w}_j, \ i = 1,...,240; \ j = 1,...,3 \tag{7.8}$$

where x_{ij} is the efficiency score generated by the *j*th model (j =1,…,3 for SIDF, VRS DEA and CRS DEA models, respectively) for the *i*th farm household and $\tilde{w}_j$ is the transformed $\hat{w}_j$. φ_i is the weighted sum of the efficiency scores generated by the SIDF, VRS DEA and CRS DEA models. The model is implemented in STATA version 10.0.

7.3. Results and Discussion

7.3.1 Final Efficiency Scores and Distribution from the Integrated Model

The results of efficiency distributions and some descriptive statistics from the integrated model are present in table 7.1. Final technical efficiency (TE) ranges from 56.6 to 98.9 with a mean of 84.2 percent. This implies that if farm households will operate on the frontier, they will achieve a cost savings of 15.8 percent without reducing output. On the other hand, if the average farm household in the sample was to achieve the TE level of its most efficient counterpart, then the average farm household could realize a 14.87 percent cost savings (i.e., 1–[84.2/98.9]). A similar calculation for the most technically inefficiency farm household reveals cost saving of 47.8 percent (i.e., 1– [56.6/98.9]).

Table 7.1: Frequency distribution of efficiency scores from the integrated model

Efficiency level (%)	TE		AE		CE	
	Number	Percent	Number	Percent	Number	Percent
≤ 40	0	0.00	20	8.33	44	18.33
41-50	0	0.00	24	10.00	48	20.00
51-60	10	4.17	45	18.75	67	27.92
61-70	18	7.50	47	19.58	61	25.42
71-80	50	20.83	67	27.92	15	6.25
81-90	88	36.67	34	14.17	4	1.67
91-100	74	30.83	3	1.25	1	0.42
Mean	84.2		65.7		54.5	
Min	56.6		25.4		21.4	
Max	98.9		96.1		95.3	
SD	10.8		15.3		13.6	
CV	12.7		23.3		24.9	

CV = coefficient of variation; Min = Minimum; Max = Maximum; SD = Standard deviation

The average allocative efficiency (AE) of the sample is 65.7 percent with a low of 25.4 percent and a high of 96.1 percent. This implies that there is room to improve allocative efficiency of the farm households by 34.3 percent to have them operate on the frontier. It also suggests that if the average farm household was to achieve the AE level of its most efficient farm household, then the average farm household could achieve a cost saving of 31.6 percent while the least efficient farm household would achieve a cost saving of 73.6 percent.

Cost efficiency (CE) ranges from 21.4 to 95.3 with a mean of 54.5 giving room for cost efficiency improvement by 49.5 percent, if farm households were to operate on the frontier and also suggests a gain economic efficiency of 42.8 percent for the average farm household and 75.5 percent for the least efficient farm household. The general conclusion of these results is that maize farmers in Benue State operate with considerable inefficiency which is dominated by cost inefficiency thereby providing an avenue for policy interventions that would help reduce inefficiency.

7.3.2 Impact of Technological Innovation on Efficiency Estimates from the Integrated Model

A major goal of this section is to evaluate the impact of technological innovation on farm efficiency using the integrated model. Two approaches are followed here. First, a t-test of difference in means of technical, allocative and cost efficiency generated from the integrated model for adopters and non-adopters of each technology was conducted. Second, an empirical evidence of the direction and magnitude of the impact of technological innovations and other policy variables on farm efficiency is provided in a second stage Tobit regression.

The test of difference in mean technical efficiency for improved and traditional maize farm households are presented in table 7.2. Results show that for the hybrid seed, the technical, allocative and cost efficiency values are higher for adopters than for non-adopters though only the technical and cost efficiency results are significant. Similar result was obtained for conservation practices variable. The results of the fertilizer technology depict that farmers who applied fertilizer on their maize farms were less technically efficient but more allocatively efficient than those who did not. Further, the t-test result shows that farmers who used herbicides were more technically efficient but less allocatively efficient than those who did not use herbicides on their farm. Since the results for hybrid seed and conservation technology were more

Table 7.2: Efficiency estimates and test of difference in means for traditional versus improved maize farmers

		HYV	
	TE	**AE**	**CE**
Improved:			
Mean	0.862	0.657	0.559
Min.	0.588	0.254	0.214
Max.	0.989	0.961	0.953
SD	0.092	0.154	0.134
Traditional:			
Mean	0.767	0.656	0.491
Min.	0.566	0.305	0.272
Max.	0.984	0.871	0.798
SD	0.132	0.153	0.129
t-ratio	5.905	0.063	3.220
		AFERT	
	TE	**AE**	**CE**
Improved:			
Mean	0.837	0.663	0.547
Min.	0.566	0.254	0.214
Max.	0.989	0.961	0.953
SD	0.109	0.156	0.140
Traditional:			
Mean	0.920	0.559	0.514
Min.	0.842	0.514	0.457
Max.	0.981	0.605	0.586
SD	0.045	0.027	0.043
t-ratio	-2.933	2.590	0.912
		HERB	
	TE	**AE**	**CE**
Improved:			
Mean	0.861	0.643	0.547
Min.	0.566	0.254	0.214
Max.	0.989	0.961	0.953
SD	0.100	0.157	0.143
Traditional:			
Mean	0.809	0.681	0.540
Min.	0.576	0.308	0.282
Max.	0.981	0.913	0.900
SD	0.114	0.145	0.122
t-ratio	3.725	-1.883	0.412
		PRACTICES	
	TE	**AE**	**CE**
Improved:			
Mean	0.877	0.665	0.576
Min.	0.610	0.300	0.276
Max.	0.989	0.961	0.953
SD	0.084	0.148	0.129
Traditional:			
Mean	0.781	0.643	0.490
Min.	0.566	0.254	0.214
Max.	0.986	0.886	0.823
SD	0.120	0.162	0.130
t-ratio	7.269	1.041	4.936

consistent than those for fertilizer and herbicides, one can argue for more public investment in development and diffusion of improved maize technologies especially hybrid maize seed and conservation technologies as these could improve productivity and food security without endangering environmental sustainability.

For direction and magnitude of impact of technological innovation on efficiency, an endogeneity-corrected Tobit model is employed in the second step regression. Summary results for the Smith and Blundell (1986) test of exogeneity of the technological innovation variables is presented in table 7.3. It is noted that the exogeniety of hybrid seed was rejected in all the efficiency models. Therefore, the analysis is conducted using the predicted values of the hybrid seed. The exogeniety of other technological innovation variables could not be rejected in any of the efficiency models.

Table 7.3: Summary of Smith-Blundel test for exogeneity

Predicted residuals	TE	AE	CE
RES_HYV	0.080****	-0.150***	-0.066***
	(0.021)	(0.034)	(0.024)
RES_AFERT	-0.019	-0.044	-0.050
	(0.029)	(0.046)	(0.031)
RES_HERB	0.005	-0.042	-0.034
	(0.025)	(0.041)	(0.028)
RES_PRACTICES	0.005	-0.004	-0.005
	(0.009)	(0.015)	(0.010)

***Significant at 1 per cent level; ***significant at 5 per cent level; *significant at 10 per cent level. Standard errors are shown in parenthesis.

The estimated coefficients and marginal effects from the second stage endogeneity-corrected tobit model are presented in table 7.4. The significance of the likelihood ratio (LR) test in each of the integrated efficiency model implies that all the variables included are jointly significant in influencing technical, allocative and cost efficiency. Thus, the hypothesis that the technology and other policy variables included in the model have no significant impact on technical, allocative and cost efficiency is rejected. AGE has positive relationship with technical, allocative and cost efficiency but the influence is significant on technical efficiency only. Thus, the variable indexes experience and serve as a proxy for human capital showing that farmers with greater farming experience will have better management skills and thus higher efficiency than younger farmers. The second human capital variable, education (EDU) has positive and significant impact on technical efficiency implying that the more educated a farmer is the more he is able to produce at or near the frontier. Household size (HHS) was found to be positively and significantly related technical efficiency indicating the importance of abundant labour supply. LAND has positive and significant impact on allocative and cost efficiency only. The implication of this result is that larger farmers are more efficient in choosing cost-minimising input combinations than smallholder farmers.

MFG indexes social capital and affords the farmers opportunity of sharing information on modern maize practices by interacting with others as well as provides farmers with bargaining power in the input, output and credit markets. As expected, MFG was found to be consistently positive but it has significant impact on technical efficiency only. CREDIT has positive and significant impact on allocative and cost efficiency. The availability of credit loses the production constraints thus facilitating timely purchase of inputs and therefore increases productivity via efficiency.

Finally, an important goal of this study is to evaluate explicitly the impact of technological innovation on efficiency of maize farmers. Results from the integrated model show that, hybrid seeds (HYV) has positive and significant impact on technical, allocative and cost efficiency. These findings further strengthen the need for hybrid seed improvement and diffusion in Nigeria in line with the current doubling of maize production programme of the federal government. The use of inorganic fertilizer, AFERT was also found to have positive and significant impact on the allocative and cost efficiency.

PRACTICES have positive impact on all the efficiency measures though this impact is only significant for technical and cost efficiency. This implies that that economic and environmental sustainability can be viewed as complementary rather than competitive goals. The impact of these improved technologies on farm efficiency is not surprising as the yield benefits is expected to cushion the cost implications thereby reducing per unit cost of production, hence farmers who adopted these technologies are more technically, allocativelly and economically efficient than those who did not.

Table 7.4 Tobit model results of impact of technological innovation on efficiency

Variable	Technical efficiency		Allocative efficiency		Cost efficiency		Mean
	Coeff.	M.E	Coeff.	M.E	Coeff.	M.E	
GENDER	-0.024	-0.021	0.013	0.013	-0.008	-0.008	0.888
	(0.016)	(0.014)	(0.026)	(0.026)	(0.018)	(0.018)	
AGE	0.002***	0.002***	-0.001	-0.001	0.001	0.001	47.167
	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	
EDU	0.003***	0.002***	0.001	0.001	0.001	0.001	8.433
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	
HHS	0.001*	0.001*	0.001	0.001	0.002**	0.002**	11.742
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	
LAND	0.013	0.012	0.042*	0.041*	0.067***	0.067***	1.208
	(0.015)	(0.014)	(0.025)	(0.025)	(0.017)	(0.017)	
OFFWORK	-0.013	-0.011	-0.004	-0.003	-0.013	-0.013	0.675
	(0.011)	(0.010)	(0.018)	(0.017)	(0.012)	(0.012)	
MFG	0.061***	0.054***	0.018	0.018	0.031	0.031	0.454
	(0.018)	(0.016)	(0.030)	(0.029)	(0.020)	(0.020)	
EXT	-0.003	-0.003	0.008	0.008	0.004	0.004	2.546
	(0.003)	(0.003)	(0.005)	(0.005)	(0.003)	(0.003)	
CREDIT	0.011	0.010	0.157***	0.145***	0.147***	0.147***	0.138
	(0.015)	(0.013)	(0.025)	(0.021)	(0.017)	(0.017)	
MARKET	-0.001	0.001	-0.001	-0.001	0.000	0.000	6.278
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	
HYV	0.021**	0.019**	0.048***	0.047***	0.035***	0.035***	0.895
	(0.011)	(0.009)	(0.017)	(0.017)	(0.012)	(0.012)	
AFERT	-0.017	-0.016	0.069***	0.067***	0.057***	0.057***	0.816
	(0.017)	(0.015)	(0.026)	(0.026)	(0.018)	(0.018)	
HERB	0.014	0.013	-0.023	-0.022	-0.007	-0.007	0.591
	(0.012)	(0.010)	(0.019)	(0.018)	(0.013)	(0.013)	
PRACTICES	0.013***	0.012***	0.001	0.001	0.008**	0.008**	1.75
	(0.004)	(0.004)	(0.006)	(0.006)	(0.004)	(0.004)	
INTERCEPT	0.650***		0.536***		0.281***		
	(0.035)		(0.057)		(0.039)		
LLF	270.354		155.880		249.203		
LR TEST	166.250***		103.130***		232.440***		

***Significant at 1% level; **significant at 5% level; *significant at 10% level. Standard errors are shown in parenthesis; M.E. = marginal effect

7.4 Conclusions

The results show that farmers who used either traditional or improved technologies were technically, allocativelly and cost inefficient. The average technical, allocative and cost efficiency are 84.2, 65.7 and 54.5 percent, respectively implying that farm households' technical, allocative and cost efficiency can be improved by 15.8, 34.3 and 45.5 percent, respectively in order to operate on the frontier. Results also show that use of hybrid seeds, inorganic fertilizer and conservation practices have positive and significant impact on farm efficiency. Control variables which also have significant impact on efficiency include education, age, household size, land size, credit, and membership in a farmer group. The results of the integrated model did not in any way hide any important information that will assist policy making as some opponents of aggregation would argue. Rather, the findings of the integrated model consolidate those of the individual models. Therefore one is confident using the integrated model when the choice between parametric and non-parametric approaches is not clear cut as is often the case in most efficiency studies.

CHAPTER 8

SUMMARY, CONCLUSIONS AND POLICY IMPLICATIONS

In this chapter, the methodology employed in this study is summarized. The summary and conclusions on the results obtained are provided and their policy implications are given. The study recognizes a number of limitations and therefore recommendations for further research are provided based on these.

8.1 Summary and Conclusion

The maize sub-sector has featured in a number of Nigeria's policy initiatives, the most current of which involves doubling of its production and productivity through promotion of improved technologies such as hybrid seed, inorganic fertilizer, pesticides, herbicides, and better management practices. Despite the policy initiatives, maize productivity has remained low raising question about the efficiency of resource use by the farmers and the benefits of the Nigeria's technology policy. For justification of further investment in development and promotion of improved maize technologies, empirical evidence is needed. The broad objective of this study is to evaluate efficiency results from both parametric and non-parametric approaches with application to small-scale maize production in Benue State, Nigeria.

There are a limited number of studies in agriculture that have dealt with technical, allocative and economic efficiency simultaneously. Among these studies only few compared results from different approaches. Majority of the comparative studies involved the parametric stochastic frontier production function and data envelopment analysis which is non-parametric. However, the use of stochastic frontier production function for decomposing cost efficiency into its technical and allocative components involves an imposition of input-oriented framework on the output-oriented stochastic frontier production function results. The resulting efficiency estimates therefore suffer from simultaneity bias. Further, the estimation of the cost frontier is not practical when there is little or no variation in input prices among farmers which is often the case in most developing countries and it is not also appropriate when there is deviation from behavioural assumptions.

This study employed the distance frontier efficiency decomposition techniques that do not suffer from the simultaneous equation bias when analysis extends to allocative and cost efficiency nor does it require variation in input prices across firms to provide valid estimates of allocative and cost efficiency. Both parametric and non-parametric distance frontiers are employed. Four specific objectives are pursued in this study. First is a comparison of the performance of technical, allocative and cost efficiency measures from both parametric stochastic and non-parametric distance functions. Second is an assessment of the impact of measuring technical, allocative and cost efficiencies relative to a distance function versus a production frontier. Third is an analysis of the effect of technology and other policy variables on technical, allocative and cost efficiencies of maize farmers in Benue State Nigeria using the different frontier models. Fourth is a provision of final technical, allocative and cost efficiency estimates and policy impacts in an integrated frontier framework.

The study used data obtained from a field survey for the 2008/2009 agricultural year. A multistage stratified sampling technique was employed in selection of respondents. There are three agricultural zones in Benue State namely, A, B and C. Zones B and C were selected in the first stage through a simple random technique. In the second stage, Buruku and Gwer East were selected from Zone B while Oju and Otukpo were selected from Zone C based on their adequate representation of distinct maize production and on active operation of Benue State Agricultural and Rural Development Agency. In the third stage, a total of 240 farm households were randomly selected and interviewed and data was collected on their production activities, technology adoption and socioeconomic characteristics.

Results from all the approaches indicated considerable technical, allocative and cost inefficiency under both traditional and improved maize technology. For the SIDF model, the average technical, allocative and cost efficiency estimates are 86.7, 57.8 and 50.3 percent, respectively. For the VRS DEA model, the average technical, allocative and cost efficiency estimates are 85.5, 65.9 and 51.6 percent, respectively. For the CRS DEA model, the average technical, allocative and cost efficiency estimates are 80.1, 65.9 and 51.6. For the SFPF model, the average technical, allocative and cost efficiency estimates are 85.3, 52.6 and 44.6, respectively. The result from all the approaches indicated that inefficiency in maize production in Benue State is dominated by cost inefficiency suggesting the immense potential of enhancing production through improvement in overall efficiency.

Two approaches were employed in the analysis of technology impact on efficiency namely t-test of equality in means and second stage Tobit regression after testing and correcting for endogeniety. The impact analysis suggest that use of hybrid seed, fertilizer, herbicides and conservation practices as well as age, education, household size, land, engagement in off farm work, membership in a farmer organization, access to extension, credit and market are significant determinants of technical efficiency in at least one of the models. For allocative efficiency, hybrid seed, inorganic fertilizer and herbicides as well as land, extension and credit are significant determinants in at least one of the models. For cost efficiency, hybrid seed, inorganic fertilizer and conservation practices as well as age, household size, land, membership in a farmer group, extension and credit are significant determinants in at least one of the models.

In addition to the comparison of absolute values of efficiency scores from the four models, formal sensitivity tests were conducted. Both parametric and non-parametric tests were conducted. These include: a t-test of equality in means and Wilcoxon signed-rank test of equality in distribution within the bilateral pairs of the employed approaches, Kruskal-Wallis and ANOVA tests of equality in variances and the Spearman rank correlation test of independence for overall consistency. The overall consistency check shows that technical, allocative and cost efficiency measures from the three distance functions (SIDF, VRS DEA and CRS DEA) were consistent whereas similar conclusions could not hold when these were compared to the production frontier (SFPF) especially for technical efficiency estimates. Given the consistency of results from the parametric and non-parametric distance functions, an integrated input distance model was developed for providing final efficiency estimates and analysis of policy impacts. This final analysis is important given the strengths and weaknesses of the different parametric and non-parametric approaches which make it difficult to justify the preference of one approach to the other.

The results of the integrated model did not in any way hide any important information that will assist policy making as some opponents of aggregation would argue. Although, results show that farmers who used improved technologies were more efficient in general than the traditional farmers. On average both group of farmers were technically, allocativelly and cost inefficient thus giving room for improvement of maize productivity for both groups. When the sample is split according to use of each of the technology innovation packages, results show that the mean technical, allocative and cost efficiency of farmers who used hybrid seeds are 86.2, 65.7 and 55.9 percent, respectively while the corresponding values are 76.7, 65.6 and 49.1, percent for those who did not use hybrid seeds.

For farmers who used inorganic fertilizers, the mean technical, allocative and cost efficiency estimates are 83.7, 66.3 and 54.7 percent, respectively while the corresponding values are 92.0, 55.9 and 51.4 percent for those who did not use inorganic fertilizer. For farmers who used herbicides, the mean technical, allocative and cost efficiency estimates are 86.1, 64.3 and 54.7 percent while the corresponding values for those who did not use herbicides are 80.9, 68.1 and 54 percent.

For farmers who used conservation practices, the mean technical, allocative and cost efficiency estimates are 87.7, 66.5 and 57.6 percent, respectively while the corresponding values for non-users are 78.1, 64.3 and 49 percent. It can be observed that in almost all cases, the technical efficiency of traditional maize producers are lower than those of improved maize producers.

When the full sample is considered, the average technical, allocative and cost efficiency are 84.2, 65.7 and 54.5 percent, respectively implying that there is a possibility of raising maize production by 45.5 percent through overall efficiency improvement. Under the integrated approach, the study revealed that hybrid seeds, inorganic fertilizer and conservation practices have positive and significant impact on farm efficiency. Other determinants of efficiency include education, age, household size, land size, credit, and membership in a farmer group.

8.2 Policy Implications

A number of agricultural policies and or initiatives have been put in place to foster the growth of maize in Nigeria. For instance, the 2006 presidential initiative of doubling maize production and the 2008 President Umaru Yaradua seven-point agenda which also featured maize as an important crop were all targeted at the growth of maize and other major crops. However, productivity still remains low. Based on the findings of this study, resources are not efficiently used by maize farmers owing to a number of factors which include limited use of modern technologies such as improved maize seed, inorganic fertilizers and conservation practices, smallness of farm holdings, inadequate formal education, access to extension services and credit. Similar results were found by other Nigerian researchers. For instance, Ogundele and Okoruwa (2004) found that the use of improved rice varieties and area expansion had positive influence on technical efficiency. Further, Okoye et al. (2006) found that the use of inorganic fertilizer had positive impact on allocative efficiency on cocoyam farmers.

The positive and significant impact of hybrid seed calls for the Nigerian government to invest more in research and development that will produce a viable seed sector in the country. Greater availability and accessibility of inorganic fertilizers is very crucial as these could enhance the efficiency of smallholder farmers. This was also evidenced in the under-utilization of fertilizer as a production input. Given the escalating prices of inorganic fertilizers, alternatives such as soil conservation practices which reduce the effective costs of soil fertility management options are necessary. This should essentially form an important extension package to all farmers since the goal of economic benefits and environmental sustainability must be balanced. In view of the interactions among the agricultural technology packages, it is argued that adoption of the whole package would be more profitable than adopting a component or some components of the technology package. From these findings, a further investment in agricultural research and development is necessary for increasing efficiency and productivity of maize production and subsequently reducing food insecurity and poverty alleviation in Nigeria.

The positive relationship between access to credit and efficiency of the farmers implies that policies that will make micro-credit from government and non-governmental agencies accessible to these farmers will go a long way in addressing their resource use inefficiency problems. These would help farmers to purchase critical inputs like fertilizers and hybrid seeds. Given the significance of education, policies to provide adequate funding for the universal basic education programme in Nigeria should be given urgent priority. The role of education cannot be overstressed as it enhances farmers' skills and understanding of seemingly complex techniques. A review of agricultural policy with regard to renewed public support to revamp the agricultural extension system is needed. The quality and adequacy of extension services in Nigeria needs to be upgraded. Proper training needs to be provided for extension agents in order to enhance effective delivery of the innovation messages to farmers. In other words, additional efforts should be devoted to upgrade the skills and knowledge of the extension agents as well as ensuring timely dissemination of modern technological inputs and practices.

The design and implementation of policies and strategies that would encourage farmers to form farmer organisations or join existing ones will be a step in the right direction to ensuring improvement in technical, allocative and cost efficiency and subsequently maize productivity growth. This is because these organizations serve as social capital which expands a farmer's social network and therefore provides better avenues for farmers to be well integrated into the input and output markets. In order to reap the benefits of strong farmer associations, policy on farmers associations and cooperatives must be based on the context of Nigerian rural institution's socio-economic environment and should be built on it. These associations need to be integrated as important partners within the agricultural research system of Nigeria. Government should create enabling environment for private sector promoters of farmer organizations. Adequate training of executive members of these associations on capacity building, design and implementation of projects, and policy analysis may be necessary. Recognition and reward for farmer organizations that achieve defined objectives and levels of excellence in farm production and marketing and other related areas can serve as a booster in the activities of not only the successful organization but others will attempt to emulate them.

Farmers in the study area cultivate only a small area of land and the results indicate that farmers operate with increasing returns to scale implying that the small scale of operation could be another important source of inefficiency. Hence, policies to ensure large scale of operation are recommended. This does not mean that small scale farmers should be moved out of farming. This is essentially impossible as there are only a handful of large scale farmers in Nigeria. Rather, policies to ensure that more land is allocated for farming purposes are recommended. In essence, commercialization of maize production in Nigeria would be a step in the direction towards increased productivity. In the long run it is expected that these small scale farmers today will eventually become the large scale farmers tomorrow and hence will benefit from any land expansion policy.

In conclusion, appropriate policy formulation and implementation is an effective instrument to improvement in farm efficiency and productivity which promotes overall growth of the economy. Although, the promotion of improved technologies is an important instrument in increasing agricultural productivity, it is not sufficient to make the needed necessary impacts on rural livelihood and the economy at large. Therefore, complementary policies which include investment in education, land expansion, improvement in the extension system, efficient credit delivery system including access to credit from both micro-credit and commercial banks and enabling market oriented policies must also form part of the strategy. Finally, there is a need for all the stake holders (both the public and private sector) to make concerted efforts to remove the bottlenecks that have constrained effective policy implementation and its accrued benefits in the Nigerian agriculture.

8.3 Limitations of the Study and Areas for Future Research

This study was conducted on a single crop, that is, maize production. Farms may neither keep good records nor recall accurately input allocations among different crops and hence this poses a limitation in this study. However, the methodology employed in this study accommodates multiple outputs and therefore, an extension of this study to analysis of either the multiple crops is recommended. The study is limited by dearth of household panel data in Nigerian agriculture. A better understanding of impact of technology on production efficiency and productivity could be provided in a dynamic framework. An extension to a panel study that incorporates both the fixed and random effects parameters is recommended.

The study estimated a single frontier for both adopters and non-adopters given the wide range of technology innovation variables studied. Aggregate index of technological innovation may be computed to verify the impact of this single index on production efficiency and productivity. In this case, separate frontiers can be estimated for each group of farmers. Further, the study did not consider scale effects on the estimated efficiencies. This can be another area of study.

The study considered non-statistical DEA models. An understanding of the statistical properties of efficiency estimates from DEA models cannot be overstressed. Given recent developments in statistical DEA models, an extension of this work using the bootstrapped DEA model will be interesting. This might eliminate or reduce some of the bias often witnessed in non-statistical DEA results.

Finally, frontier analysis is, by definition, a best practice benchmark methodology, therefore the efficiency scores and results obtained in this study are relative to the observed population, in this case maize farms in Benue State Nigeria, characterized by low level of productivity by hectare. Therefore, absolute efficiency scores may drop dramatically if same farms were pooled in the same sample with maize farms in other countries and regions of the world. Therefore, an extension of the study to other countries and regions where it is possible to study efficiency of large scale farmers using similar methodology as in this study may be a good idea.