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Technical Efficiency of Rain-Fed Irish Potato Farmers in Plateau State, Nigeria: A Stochastic Frontier Approach

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Abstract
This study estimated technical efficiencies and identified the determinants of technical efficiencies of rain-fed Irish potato farmers in Plateau State, Nigeria. A multistage sampling techniques involving purposive and random sampling was used to obtain data from a study sample of 227 respondents using structured questionnaires during the 2012/2013 cropping season. Data were analyzed using stochastic frontier production function. Results showed that rain-fed Irish potato farmers were experiencing decreasing return to scale in the use of farm resources. This is confirmed by the estimated return to scale parameter of 0.958. The study also showed that technical efficiency ranges from 2.37% to 95.6% with a mean technical efficiency of 74%. This widely varying indices of technical efficiency among the rain-fed Irish potato farmers indicates great potential to achieve productivity growth through improved efficiency using existing technologies and the available resource base in the study area. The determinants of technical efficiencies were education, farming experience, potato variety and off-farm income. The study recommended that policies that would directly affect the identified determinants of technical efficiency be pursued by the relevant authorities.
Keywords: Technical efficiency, inefficiency, stochastic frontier, Irish-potato, Plateau State, rain-fed production.

Introduction
Irish potato is the World's fourth largest food crop after wheat, rice, and maize. World production reached a record of 324 million metric tons in 2010 and production in the developing countries has almost double since 1991 (FAOSTAT, 2012). In Nigeria, the total annual production estimate was 54,000; 599,000; 800,000; and 900,000 metric tons in 1990, 2000, 2008, and 2010, respectively. Irish potato has the potential to relieve the pressure of food insecurity on the rural poor farmers since the crop has a short maturity period. It matures in about 60 to 90 days, giving it the advantage of being cultivated two to three times a year (Okunade and Ibrahim, 2011 & NRCRI, 2005).

About 95% of Irish potato produced in Nigeria comes from Jos Plateau which has near temperate climatic conditions that favor Irish potato production (NRCRI 2005). According to Okonkwo *et al* (1995), Irish potato can be grown on the Obudu Highlands, Mambilla Plateau and Biu Plateau in Cross Rivers, Taraba and Borno State, respectively. Research also revealed that during the cold harmattan periods of November to February, Irish Potato can also be grown under irrigation in most Northern States of Nigeria (NRCRI, 2005).

Irish potato is grown for food as well as cash crop. It is a major source of income among the rural farmers during the rainy and dry season in the producing areas. Its production and marketing has become an integral part of the rural economy in the highland zones of Plateau State (Mohammed, 2009).

Given the fact that Nigeria is predominantly an agricultural country (Ndanitsa *et al*, 2009) having about 80 to 90 percent of its rural population involved in agricultural food production (Akpan, 2009), nevertheless, Ashigidigbi, *et al* (2011) reported that Nigeria have food demand exceeding its local production. This indicates that Nigeria lags far behind in providing food for her ever increasing population. Nigeria therefore is faced with a great challenge in terms of inadequacy of food supply. It therefore becomes imperative to evaluate the current level of efficiency of farm units given that efficiency of farm production is directly related to the overall productivity of agricultural production. According to Ogundari and Aladejimokum (2006), measuring the level of and determinants of efficiency of farm units provide decision and policy makers with policy options for raising the present level of agricultural productivity in the country. Increase production and productivity are direct consequence of efficiency of production resulting from efficiency of input combinaton, given the available technology.

According to Olajide and Heady (1982), farm productivity is the index of the ratio of the value of total farm output to the value of total inputs used in farm production (Efficiency). Optimal productivity is the efficient utilization of resources used in production process. In this context, farm productivity is synonymous with production efficiency. Efficiency, therefore, is an important factor in productivity growth.

In an economy where resources are scarce and opportunities for new technologies are lacking, inefficiency studies will be able to show that it is possible to raise productivity by improving efficiency without raising the resource base or developing new technology (Tijani, 2006). Estimate of the extent of inefficiency also help in deciding whether to improve efficiency or to develop new technology to raise farm productivity. The objectives of this study, therefore, are to estimate the technical efficiency of rain-fed Irish potato farmers, and identify determinants of technical efficiency among rain-fed Irish potato farmers in Plateau State, Nigeria.

Theoretical framework

The concept of efficiency is concerned with the relative performance of the process used in transforming given inputs into outputs. Economic theory identifies at least three types of efficiency –technical, allocative and economic efficiency. Allocative efficiency refers to the choice of optimum combination of inputs consistent with the relative factor prices. Technical efficiency shows the choice of farm firms to employ the best practice in a farm industry, so that no more than the necessary amount of a given sets of inputs is used in producing the best level of output. Economic efficiency is the product of technical and allocative efficiencies.

Efficiency is very important factor of productivity growth, especially in developing agricultural economics where resources are meager and opportunities for developing and adopting better technologies are dwindling (Ali and Chaudhry, 1990). Such economies can benefit greatly by determining the extent to which it is possible to raise productivity or increase efficiency at the existing resource base or technology. For efficient production, non-physical inputs such as experience, education levels, age and extension visit might influence the ability of famers to use the available productive and technological resources efficiently. Each type of inefficiency is costly to a productive unit in the sense that each type of inefficiency causes a reduction in output and profit below the maximum value attainable under full efficiency.

The two most popular methods of measuring efficiency, assuming the presence of inefficiency effects in the production system are Data Envelopment Analysis (DEA) and the Stochastic Frontier Analysis methods. Coelli (1995) compared the two methods and concluded that the main strengths of the Stochastic Frontier approach are its ability to deal with stochastic noise and the incorporation of statistical hypothesis tests pertaining to production structure and degree of inefficiency. Most studies use stochastic frontier to measured technical efficiency because of the stated advantages. Ajibefun *et al*, (2002), Tijani, (2006) and Ashagidigbi *et al,* (2011) among others have used the stochastic parametric model to measure the technical, allocative and economic efficiencies in recent agricultural production efficiency studies.

Methodology

The study was conducted in the major Irish Potato producing Local Government Areas (LGAs) of Plateau State (Bokkos and Mang LGAs). Plateau State lies between latitude 8^0 30 and 10^0 30'' and longitudes 7^0 30' and 3^0 37. The state has a land area of 30913km^2 with an estimated population of 3,553,440 (NPC 2006). The state has a near temperate climatic condition that favor crops like Irish potatoes, apples, grapes, wheat, barley and many other exotic crops. The state has rainfall season running from April to October and a dry season with a cold dry harmattan wind that prevails over the state from November to February.

A multistage sampling technique was used in the selecting the study sample. The selection of the two LGAs was purposive due to the high concentration of rain-fed Irish potato farmers in those areas. From each LGA three districts were randomly selected and a list of the rain-fed Irish potato farmers was compiled in each selected district. From the list in each district, 40 rain-fed Irish potato farmers were randomly selected to give a total of 240 respondents.

Structured questionnaire was used to collect primary data from the 240 respondents during the 2012/2013 cropping season. Data were collected on socio-economic characteristics of the respondents, Irish potato farm size, value of fertilizer, labour, seeds and the value of Irish potato output.

According to Kopp and Smith (1989), functional forms have limited effects on empirical efficiency measurement. Cobb-Douglas forms have been used in many studies, particularly in those relating to developing agricultures. According to (Battesse, 1992), the Cobb-Douglas functional form meets the requirement of being self-dual, allowing an examination of economic efficiency, therefore, this study employed the following Cobb-Douglas functional form to model rain-fed Irish potato production technology in the study areas.

$LogY_i=b_o+b_ilogX_{1i}+b_2logX_{2i}+b_3logX_{3i}+b_4logX_{4i}+b_5logX_{5i}+b_6logX_{6i}+V_i+U_i$ …………1

Where:

i = the i-th potato farmer

Y_i = Irish potato output of the i-th farmer

B_s = regression coefficients

X_{li} = Farm size (Ha)

X_{2i} = Labor (Man days)

X_{3i} = seed (kg)

X_{4i} = chemical fertilizer (kg)

X_{5i} = Organic fertilizer (kg)

X_{6i} = Agro-chemicals

V_i = statistical disturbance term (random error term)

U_i = technical efficiency effect independent of V_i.

According to Coelli, (2005), the factors responsible for technical inefficiency of the rain-fed Irish potato farmers are a function of socio-economic factors expressed as:

$U = \delta_0 + \delta_{1i}Z_{1i} + S_2Z_{2i} + \delta_3Z_{3i} + S_4Z_{4i} + S_5Z_{5i} + S_6Z_{6i} + \delta_7Z_{7i}$ …………………………….. 2

Where:

U = inefficiency function

Z_{1i} = Age of farmers

Z_{2i} = Educational level

Z_{3i} = years of experience

Z_{4i} = household size

Z_{5i} = Variety of Irish potato

Z_{6i} = Extension visit (contact)

Z_{7i} = Annual off-farm income.

The maximum likelihood estimates(MLE) of the parameters in the Cob-Douglas stochastic frontier production function model and the technical inefficiency effects were obtained using FRONTIER 4. 1 (Coelli, 1994). The values of unknown coefficients in equation (1) and (2), that is, the b_s and the δ_s can be obtained jointly using the maximum likelihood method (ML). An estimated value of technical efficiency for each farmer was then calculated in $TE_{1i} = \exp(-U_i)$

Results and Discussions

The maximum like hood estimates (MLE) for the mean-difference of the stochastic frontier production function for the rain-fed Irish potato farmers is presented in table 1. The estimated elasticity of mean output mean with respect to farm size, labor, seeds, chemical fertilizers, organic fertilizers and agro-chemicals were -0.00114, 0.334, 0.519, 0.105, 0.0336 and -0.004, respectively. These coefficients represent percentage change in dependent variable as a result of percentage change in the independent variables. In other words, a 10% increase in labor, seeds, chemical fertilizers and organic fertilizers will raise Irish potato output by 3.35%, 5.19%, 1.05% and 0.34%, respectively. But a 10% increase in farm size and agro-chemicals will decrease Irish potato output by 0.011% and 0.04%, respectively. The elasticity estimates of seed and labor were statistically significant at 1% levels of probability, respectively; while that of chemical fertilizer was significant at 5% level. Farm size, organic fertilizer and agro chemicals were statistically insignificant at all conventional levels of probability. These results indicated the relative importance of these inputs in rain-fed Irish potato production in the study area. Labor, seeds and chemical fertilizers appeared to be most important imputs, being consistent with the observation that these inputs were not readily available at affordable price to the rain-fed Irish potato farmers in the study area. This finding concurs with those of kudi *et al,* (2008) and Muthoni *et al,* (2009), that labor is the most important variable in Irish potato industry because the enterprise is labor intensive, and that in addition, Irish potato seeds and chemical fertilizers determine to a large extend the productivity and net return of rain dependent Irish potato farmers in developing countries.

The policy implication here is that it is imperative for the government and Non- Governmental Organization (NGOs) to continue with their effort to make seeds and chemical fertilizers available to farmers at affordable prices and at the right time. In the same vane, the government of Plateau State, through her Agricultural Service and Training Centres (ASTCs), should intensify her effort of making available tractor hiring services to farmers at affordable rate and on time. Alternatively the rain dependent Irish potato farmers should form farm cooperation to make available labor supply at reduced cost.

Farm size and agro-chemicals appeared to be over used because of the negativity of their coefficients. In other words farm size and agro-chemicals were utilized in stage III of the production function, where marginal physical product is negative and Total physical product is declining absolutely.

Using the significant coefficient only, the returns to scale (RTS) parameter is estimated to be 0.958 which implies that a one percent (1%) increase in the use of the productive resources will lead to a 0.96% increase in the output of rain-fed Irish potato produced. This analysis reveals a decreasing return to scale in the rain-fed Irish potato farms in the study area.

Table 2 shows the MLE for technical inefficiency in the stochastic frontier production function of the rain-fed Irish Potato farmers. Results showed that the variance ratio defined by Gamma ($Y = Șu^2/Șu^2+Șv^2$) is estimated to be 98.4% meaning that about 98% of the discrepancies between observed rain-fed Irish potato output and the frontier output were due to technical inefficiency. In other words, the shortfall of the observed output from the frontier output was primarily due to factors within the control of the rain-fed Irish potato farmers. Analysis in Table 2 also revealed that the coefficients of the determinants of technical inefficiency – education (-0154), Farming experience (-1.348), potato variety (-0.951) and off-farm income (-0.434) were negative while extension visits (0.369) was positive. All of these variables were statistically significant at 5% level of probability, indicating that they contributed significantly to technical inefficiency of rain-fed Irish potato production in the study area. In another way round, technical inefficiency decreases with increase in educational level, farming experience, availability of improved potato seeds and off-farm income of the farmers but increases with increase in extension visits. This finding is contrary to the findings of Bifarin *et al*. (2010) who found that extension visit contributed positively to technical efficiency in agricultural production in developing economies. The fact that extension visits was significant but with an unexpected negative relationship with technical efficiency deserves further research.

The policy implication is that technical efficiency would increase if government intervention focuses on, farmer's education, timely supply of a affordable improved seed and young farmers with longer years of faming experience. Potato farmers should as well engage in off-farm income generating activities so as to boost their personal savings towards Irish potato farming in the study areas.

Table 3 showed the distribution of technical efficiency among the rain-fed Irish potato famers. The table revealed that a wide variation in the levels of technical efficiency among the farmers. The technical efficiency range from 2.37% to 95.6% with a mean technical efficiency of 74%. This indicates that an average rain-fed Irish potato output falls 26% short of the maximum possible level. Therefore, in the short run it is possible to increase rain-fed Irish potato output in the study area by an average of 26% through the adoption of the technology used by the best and most efficient rain-fed potato farmers in the study area.

Table 3 showed that majority (80.61%) of the rain-fed farmers belongs to the most efficient category (61-100%) while few (19.38%) were less efficient (01-40%). Most of the farmers were efficient probably due to the fact that they had bigger farmlands, higher level of formal education and that they adhered to stipulated proper fertilizer applications and the use of good potato seeds. Although on average the technical efficiency of the rain-fed Irish potato farms is good, however, there was no farmer that had technical efficiency of 100%. This implies that improved technical efficiency in rain-fed Irish potato production is still possible in the study area without any improvement in the resource base or introduction of new technologies especially among the less efficient farmers. Similar results were obtained by Amos (2007) and Tijani (2006) who demonstrated that great potentials exist to increase gross output and net profit among smallholder farmers in developing countries through improved utilization of the existing levels of technology and resource base.

The estimated coefficients for the inefficiency functions (Table 2) provide some explanation for the relative efficiency levels among the rain-fed Irish potato farmers. Five of the efficiency variables: education level, farming experience, Irish potato variety, extension visit and off-farm income were statistically significant at the conventional levels, but those of age and household size were statistically insignificant. This implies that the farmers educational levels, farming experience, potato seeds and off-farm income appeared to have let to the higher levels of technical efficiency recorded.

CONCLUSION

The study estimated technical efficiencies and identified the determinants of technical efficiency of rain-fed Irish potato farmers in Plateau State, Nigeria, using stochastic frontier production model.

Results of the MLE revealed that labor, seeds and chemical fertilizers had positive coefficients, in other words, any increase in the amount of these variables lead to increase in rain-fed Irish potato output in the study area.

Findings also showed that technical efficiency indices varied widely from 2.37% to 95.6% with a mean technical efficiency of 74%. The study observed that majority (80.61%) of the farmers belong to the efficient catigory (61-100) while few (19.38%) belong to the less efficient (01-40%) category. Though this performance is good, no farmer had a technical efficiency of 100%. This implies that using the current resource base, improved efficiency can still be achieved.

The results of the inefficiency model revealed that farmer's education level, year of experience in potato farming, off-farm income and availability of improved potato seeds contributed significantly and positively to technical inefficiency while extension visit had a significant impact but had an inverse relationship with technical inefficiency, a situation which deserves further investigation.

The study finally recommended that policy interventions that directly affect the identified determinants of technical efficiency be pursued by the relevant authorities.

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Table 1: maximum likelihood estimate for technical efficiency parameters in the stochastic frontier production model

Variables	Parameters	Coefficient	t-ratio
stochastic frontier production			
Constant	b_0	3.285	100.606**
Ln farm size	b_1	-0.00114	0.0200
Ln labour	b_2	0.334	4.229**
Ln seed	b_3	0.519	11.666**
Ln chemical fertilizer	b_4	0.105	2.186*
Ln organic fertilizer	b_5	0.0336	1.233
Ln agro-chemicals	b_6	-0.00424	-0141

** Significant at 1%, * Significant at 5% level of profitability
Source: Analysis of field data, 2013.

Table 2: maximum likelihood estimate for technical efficiency parameters in the stochastic frontier production function

Variables	Parameters	Coefficient	t-ratio
stochastic frontier production			
Age (Z_1)	δ_1	0.319	0.672
Educational level (Z_2)	δ_2	-0.154	-2.105*
Farmingexperience Z_3	δ_3	-1.348	-2.224*
Household size Z_4	δ_4	-0.00657	-0.0128
Potato variety Z_5	δ_5	-0.951	-2.540*
Extension Z_6	δ_6	0.369	2.717*
Off farm income Z_7	δ_7	-0.434	-2.340*
Sigma-square ($\delta^2 = \delta u^2 + \delta v^2$)		1.995	3.402*
Gamma ($Y = \delta^2 / \delta u^2 + \delta v^2$)		0.984	157.906*
Ln likelihood function		85.033	
LR test		131.618	

** Significant at 1% * Significant at 5% level of profitability
Source: Analysis of field data, 2013

Table 3: distribution of farmer –specific technical efficiency

Technical efficiency	Frequency	Percentage
0.01-0.20	2	0.88
8.21-0.40	8	3.52
0.41-0.60	34	14.98
0.61-0.80	65	28.63
0.81-1.00	118	51.98
Total	227	100.00
Mean technical efficiency	0.740	
Minimum	0.0237	
Maximum	0.956	

Source: Analysis of field data, 2013