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Relationship between land fragmentation and maize farmers' productivity in northern Nigeria

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ABSTRACT

There exist in the literature diverse claims on the concept of land fragmentation with respect to its benefits and costs. To verify these claims, this paper sought to empirically establish the relation between land fragmentation as measured by Simpson index and the technical efficiency of maize farmers in northern Nigeria. Cross sectional surveys were conducted on a sample of 114 maize producers in eight communities of Kaduna State in northern Nigeria during 2006 cropping season. Stochastic frontier production model was used to estimate the individual farmers' technical efficiency and the Simpson Index was specified as a function of technical efficiency and other socioeconomic characteristics that could affect farmers' decisions to cultivate more plots of land. The results revealed that the technical efficiency of the sampled farmers was less than one (or less than 100%) indicating that all the maize farmers sampled were operating below the frontier. The mean technical efficiency of the maize farmers was 0.63 or 63 percent. Age, level of education, extension visit, farm mechanization, fertilizer usage, distance of farm from fertilizer market, and the technical efficiency of the farmers were the determinants of land fragmentation in the study area. The paper concluded that there existed a relationship between land fragmentation and maize farmers' productivity. Policy on land reform should be tailored towards the provision of more farmlands to allow willing farmers have access to adequate farmlands for improved productivity.

Keywords: *Land fragmentation, Simpson index, stochastic frontier, technical efficiency, Nigeria.*

INTRODUCTION

In Nigeria, agriculture still plays some significant roles in the process of economic development such as provision food for the growing population and raw materials for the industries. It is also a source of foreign exchange and helps capital formation. Despite Nigerian's enormous resources for agricultural production most especially land, a close look at the agricultural landscape reveals that activities in the food crop sub-sector are continuously dominated by production on several small and scattered landholdings (Olayide *et al,* 1980). This category of farms produces high percentage of the total food output in Nigeria as majority of the population is involved in Agriculture.

In spite of the contribution of small and scattered landholders, there has been controversy on the benefits and costs of the phenomena. Bentley (1987) claimed that fragmentation allows farms with scattered plots to benefit from risk management through the use of multiple ecozones and the practice of crop scheduling. He noted that farmers cannot only plant more diverse crops, but also grow the same crop on several different plots. Thus, fragmentation enables farmers to disperse and reduce risk by using a variety of soils and other micro-climatic and micro-environmental variations. Fragmentation also makes it possible for farmers to grow a variety of crops that mature and ripen at different times, so that they can concentrate their labor on different plots at different times, thereby avoiding household labor bottlenecks. In addition, farmers grow variety of crops, which cannot be intercropped, so they need to open more land to cultivate such crops. The costs associated with high levels of fragmentation are seen principally in terms of inefficient resource allocation (labor and capital) and the resulting cost increase in agricultural production (Shuhao, 2005). According to McPherson (1983) and Simmons (1987), land fragmentation may impose detrimental effects on agriculture in three ways: (1) creating inefficiency; (2) hindering agricultural modernization; and (3) making it costly to modify its adverse effects by consolidation schemes. In addition, land fragmentation may be detrimental to agricultural production by causing physical problems, operational difficulties and foregone investment to individual farmer. Finally, due to the existence of scale effects and externalities, investments in improved agricultural facilities, soil and water conservation, and so on are less profitable on farms with severe land fragmentation. Existing literature in Nigeria reported that these farms are characterized by low level of operation, low literacy of operators and a labour intensive production technology with hired labour cost constituting about 60% of the total cash cost of production (Olayemi, 1980; Aromolaran, 1992). In the same vein, the low level of agricultural production in the country has been linked with problems such as lack of individual responsibility on farmlands, farmland fragmentation leading to scattering of plots, little incentive for improvements, lack of security of tenure, restricted scale of operations and problems encountered in obtaining credit etc. (Fabiyi, 1983; Famoriyo *et al*., 1977; and Idowu, 1990). In spite of the associated costs, land fragmentation is still persistent and wide spread in Nigerian agriculture. This study is rooted in the diverse opinion of researchers on land fragmentation. Therefore, the study aims to empirically relate land fragmentation to maize farmers' productivity in Nigeria with a view to provide recent information to policy makers. The empirical results on land fragmentation and productivity are wanting in Nigerian agriculture. Attempts had been made by team of researchers, for example, Idowu and Oladeebo (1999) specified gross farm income as a function of total number of plots cultivated while Alene and Manyong (2006) specified technical efficiency as a function of total number of plots cultivated. The paper went a step further to specify Simpson index (a measure of land fragmentation) as a function of technical efficiency of the farmers.

The concept of land fragmentation

Land fragmentation simply put is a phenomenon that exists when a household operates a number of owned or rented noncontiguous plots at the same time. In spite of this simple definition, measures of land fragmentation are diverse. There are two approaches to measuring land fragmentation namely: single dimension indicators and integrated indicators. In the case of single dimension, one indicator is used to measure the extent of land fragmentation. Land fragmentation indicators like farm size, total number of plots in the farm, average plot size, distribution of plot sizes, spatial distribution of plots, and the shape of plots are commonly used in the literature (Bentley, 1987; Simmons, 1988). Farm size is used to measure the total holding of a farm but among the remaining parameters, size and spatial distribution (i.e. distance) are often considered to be most significant (Shuhao, 2005). The integrated indicators capture the information from several single indicators into one index. The two most popular integrated indicators are the Januszewki index and the Simpson index (Blarel *et al.*, 1992).

The Januszewki index (*JI*) is defined as: $JI = \frac{\sqrt{\sum a}}{\sum \sqrt{a}}$ where *a* is the area of each plot. This index is located within the range of 0 to 1. The smaller the *JI* value, the higher the degree of land fragmentation. The *JI* value combines information on the number of plots, average plot size and the size distribution of the plots. It has three properties: fragmentation increases (the value of the index decreases) when the number of plots increases, fragmentation increases when the average plot size declines, and fragmentation decreases when the inequality in plot sizes increases. The index, however, fails to account for farm size, plot distance, and shape of plots. The Simpson index (*SI*) on the other hand measures the degree of land fragmentation in the following way: $SI = 1 - \frac{\sum a^2}{\left(\sum a\right)^2}$ where *a* is the area of each plot. The Simpson index is also located between 0 and 1. Contrary to the *JI*, a higher *SI* value corresponds with a higher degree of land fragmentation. The value of the Simpson index is also determined by the number of plots, average plot size and the plot size distribution. It also does not take farm size, distance and plot shape into account.

Methodology

Area of study and data collected

The study was conducted in Kaduna State, northern Nigeria during 2006 cropping season. Cross sectional surveys were conducted on a sample of 114 maize producers in eight communities in the state. The dry savanna zone which Kaduna represents is characterized by low average annual rainfall and shorter growing season. In this agroecological zone, maize, sorghum, and millet are the major cereals grown. However, maize is a major cereal crop in Nigeria with the country producing 43 percent of all maize grown in West Africa (Ajala *et al.*, 1999). It is especially important in the northern guinea savannah where it is one of the two major crops in about 40 percent of the area under agricultural production (Smith *et al.*, 1997). Its importance has increased as it has replaced other food staples, particularly sorghum and millet (Smith *et al*., 1994). Data were collected through household-level surveys using structured and pre-tested questionnaires on land fragmentation, socioeconomic characteristics, crop production and cropping system.

Stochastic frontier production model specification

The stochastic frontier production function derived from the composed error model of Aigner et al. (1977); Meeusen and van den Broeck (1977) and Forsund et al. (1980) was applied in the data analysis. This model is made up of disturbance term ($\in$) which composed of two parts, a systematic term (v) and one-sided (u) component, a Cobb-Douglas production function of the following form was specified:

$$Q = g(X_a; ß) + \in_j \quad \ldots\ldots 1$$

Where Q is the quantity of agricultural output, X_a is vector of input quantities, and ß is a vector of parameters.

$\in_j$ = (error term) is defined as

$$\in_j = v_j + u_j \quad \ldots\ldots 2$$

j = 1,2,………… n farms

The two components v and u are assumed to be independent of each other, where v is the two-sided, normally distributed random error ($v \sim N(0,\sigma_v^2)$), and u is the one-sided efficiency component with a half-normal distribution $\left(u \sim |N(0,\sigma_u^2)|\right)$. The maximum likelihood estimation of Equation (1) yields estimators for β and λ, where

β = vectors of parameters, $\lambda = \sigma_u / \sigma_v$ and $\sigma^2 = \sigma_u^2 + \sigma_v^2$.

Jondrow *et al.*, (1982) have shown that the assumption made on the statistical distribution of v and u, mentioned above, makes it possible to calculate the conditional mean of u_j given $\in_j$ as:

$$E(u_j \mid \in_j) = \sigma^* \left[\frac{f^*(\in_j \lambda/\sigma)}{1 - F^*(\in_j \lambda/\sigma)} - \frac{\in_j \lambda}{\sigma} \right] \quad \ldots\ldots 3$$

Where F^* and f^* are, respectively, the standard normal density and distribution functions, evaluated at $\in_j \lambda/\sigma$ and $\sigma^2 = \sigma_u^2 \sigma_v^2 / \sigma^2$.

Therefore, Equation (1 and 3) provides estimates for u and v after replacing $\in, \sigma,$ and λ by their estimates. If v is now subtracted from both sides of (1), we obtain;

$$Q^* = f(X_a; \beta) - u = Q - v \quad \ldots\ldots 4$$

Where Q^* is the firm's observed output adjusted for the statistical noise captured by v.

On the assumption that u_j and v_j are independent, the parameters of the production frontier (Eq. 1) were estimated using maximum likelihood estimation method by an econometric software called LIMDEP Version 7.0 (Greene, 1995). The farm-specific technical efficiency (TE_j) of the j^{th} farmer was estimated by using the expectation of u_j conditional on the random variable $\in_j$ as shown by Battesse and Coelli (1988). That is,

$$TE_j = \exp(-u_j) \quad \ldots\ldots 5$$

So that $0 \leq TE_j \leq 1$

The use of the single-equation model depicted in equations (6) is justified by assuming that farmers maximize expected profits, as is commonly done in studies of this type (Zellner, Kmenta, and Drèze, 1966; Kopp and Smith, 1980; Cares and Barton, 1990; Bravo-Ureta and Evenson, 1994; Alene and Hassan, 2005). For the purpose of this study, the specific model estimated is given below:

$$\ln Q = \beta_0 + \beta_1 \ln S_i + \beta_2 \ln F_i + \beta_3 \ln L_i + \beta_4 \ln R_i + (v_i - u_I) \quad \ldots\ldots 6$$

Where

Q = Annual total farm output of maize (kg)

R = Area devoted to maize production (ha)

S = Quantity of seed used (kg)
F = Quantity of fertilizer used (kg)
L = Labor man days used in maize production
β_i = parameters to be estimated (i = 0, 1, 2, 3)
v = is the two-sided, normally distributed random error.
u = is the one-sided efficiency component with a half-normal distribution.
In = logarithm to base e

It is assumed that the extent of land fragmentation (measured by Simpson index) by the farmers is dependent on some socioeconomic characteristics of the farmers and their level of productivity. To investigate this relation, a multiple regression model using Simpson index as dependent variable was specified. The implicit form of the model is specified below.

$S_i = \beta_0 + \beta_i Z_i$ ……………………………………………………………...7

Where

S_i = Extent of farm fragmentation, measured by the Simpson index (S.I) according to Wu et al. (2005) defined as $SI = 1 - \frac{\sum a^2}{\left(\sum a\right)^2}$

a = the area of each plot
SI = index ranged between 0 and 1.
Z_i = vectors of socioeconomic variables defined as follows:
Z_1 = Age of respondents (years)
Z_2 = Educational status of maize farmers (years)
Z_3 = Household size (number of persons)
Z_4 = Number of visit of extension agents
Z_5 = Fertilizer use (1 = yes, 0 = No)
Z_6 = Distance of farm from fertilizer market (km)
Z_7 = Technical efficiency of maize farmers
β_i = parameters to be estimated (i = 0, 1, 2, 3)

Results and discussion

Farm fragmentation and productivity of maize farmers in northern Nigeria.

The Maximum Likelihood (ML) estimates for the production frontier presented in Table 1 revealed that the estimate of lambda λ (1.213) and sigma σ (0.813) are significantly different from zero at five and one percent respectively, indicating a good fit and the correctness of the specified distribution assumption. The coefficient of land (0.981) was statistically significant at one percent level and had expected positive sign, which conforms to *a priori* expectation. The positive sign shows that increasing farm size leads to an increase in maize output and vice versa. The estimated coefficient showed that maize output was elastic to changes in farm size. A 10 percent increase in farm size will bring about 9.81 percent increase in maize output.

Table 1. Stochastic production frontier for maize farmers

Variable	Coefficient	t-value
Constant	6.442	8.537***
Farm size	0.981	4.372***
Fertilizer	0.166	2.550**
Seed	0.155	1.177
Labor	0.089	0.629
Log likelihood function	-110.811	
Lambda	1.213	2.173**
Sigma	0.813	6.323***

***Significant at 1% level **Significant at 5% level

Source: Field survey, 2006

The coefficient of fertilizer variable was estimated to be positive, inelastic, and significant at five percent level. This indicated that fertilizer was a significant factor in maize production in northern Nigeria. Previous studies by Amaza (2000), Adeoti (2001) Ogundele (2003) and Awotide (2004) also reported low elasticity for fertilizer in food crop production in Nigeria. The coefficient of seed variable was estimated to be positive, inelastic, but not significant even at 10 percent level. This indicated that seed was not a significant factor in maize production. The elasticity of maize output with respect to labor was positive at (0.089) but not a significant factor that influences change in output of maize.

Technical efficiency of maize farmers in northern Nigeria

The frequency distribution of the technical efficiency indices derived from the analysis of the stochastic production and the Simpson Index is provided in Table 2. The technical efficiency of the sampled farmers was less than one (or 100%) indicating that all the maize farmers sampled were operating below the frontier. The best performing farm had a technical efficiency of 0.89 or 89 percent, while the least performing farm had a technical efficiency of 0.25 or 25 percent. The mean technical efficiency of the maize farmers was 0.63 or 63 percent. This implied that the maize farmers were able to obtain about 63 per cent of optimal output from a given set of production inputs suggesting that there is the scope for increasing maize production by 37 per cent if they were to operate at the frontier or by 11 percent if all maize farmers would adopt the technology and production techniques currently used by the most technically efficient farmer. In general, the results suggested that the sampled farmers were fairly technically efficient. The Simpson index showed that about 82 percent of the maize farmers had Simpson index ranging from 0.61- 0.80 indicating high level of land fragmentation. Likewise, about 63 percent of the farmers had technical efficiency in the same range suggesting that there exist a relationship between technical efficiency and Simpson index.

Table 2. Technical efficiency (TE) and Simpson index (SI) of maize farmers in Northern Nigeria

Categorized values of TE and SI in %	Technical efficiency		Simpson index	
	Frequency	Percentage	Frequency	Percentage
0	0	0.00	6	5.26
< 50	14	12.28	4	3.51
51-60	24	21.05	8	7.12
61-70	60	52.63	46	40.35
71-80	12	10.53	48	42.11
81-90	4	3.51	2	1.74
Total	114	100.00	114	100.00
Minimum %	25	-	0	-
Maximum %	89	-	82	-
Mean %	63	-	65	-

Source: Field survey, 2006

Relationship between land fragmentation and technical efficiency

The result of the Ordinary Least Squares regression model used to determine the relationship between land fragmentation and technical efficiency is presented in Table 3. The result revealed that the coefficient for age variable was positively and significantly related to land fragmentation suggesting that older maize farmers operate more fragmented plots than younger farmers. Educational level of the farmers showed negative relation with land fragmentation and the variable was a significant factor that influenced farmers' actions to cultivate many plots.

One possible explanation for this is that educated farmers have greater chance in the community to acquire several plots of land. The coefficient of household size was negative and was not a significant factor influencing farmers' decisions to cultivate many plots of land. There was a positive and significant relationship between extension visit and land fragmentation of maize farmers in the study area. This implies that access to extension services tends to encourage farmers to cultivate more plots. The reason for this is not far-fetched. Farmers may want to practice newly introduced technology on a newly cultivated land so as not to disrupt the existing cropping systems.

Table 3. Relationship between land fragmentation and technical efficiency

Variable	Coefficient	t-value
Constant	0.0835	0.791
Age	0.0061	3.244***
Level of education	-0.073	-2.450**
Household size	-0.031	-1.034
Extension visit	0.0292	3.241***
Farm mechanization	0.0922	3.275***
Fertilizer use	0.1320	3.104***
Distance from fertilizer market	-0.0066	-2.394**
Technical efficiency of farmer	0.3325	3.177***
Adjusted R^2	0.50	
F-value $F_{8,105}$	14.91***	

***Significant at 1% ** Significant at 5%

Source: Results from data analysis 2006

Farm mechanization is a variable that indexes the type of mechanization used by the maize farmers. In Nigeria, two main groups of tillage methods are pronounced: tractor tillage and manual tillage. Mechanized farms use tractor equipments mainly for plowing, harrowing and land area expansion. The variable was specified as a dummy variable, where one denotes tractor tillage and zero manual tillage. The coefficient of farm mechanization was positive and was significant at one percent level suggesting maize farmers using tractor tillage cultivate more plots. Fertilizer usage was statistically significant and positively related to the likelihood of land fragmentation. The reason for the development is very clear. Improved maize varieties perform better when recommended dosage of fertilizer is applied. Therefore, farmers that have access to fertilizer are likely to cultivate more land. In case the farm size is a limiting factor more plots will be cultivated elsewhere, since extreme land scarcity may lead to fragmentations as farmers in quest of additional land will tend to accept any available parcel of land within reasonable distance (Farmer, 1960). Distance of nearest fertilizer market was statistically significant and negatively related to land fragmentation suggesting that the closer the market, the more the farmers cultivate more plots. The technical efficiency of the farmers was incorporated to determine the empirical relationship between land fragmentation as measured by Simpson index and productivity of maize. The relation was found to be statistically significant and positive. The reason for the positive correlation between technical efficiency of farmers and land fragmentation is very obvious. Farmers that have higher maize yield tend to produce more by land area expansion. Fenoaltea (1976) argued that the scattered parcels enable farmers to better allocate their labour over the season. This in turn translates to higher productivity through efficient use of labour. This is contrary to the view that high levels of fragmentation are associated with inefficient resource allocation (labour and capital) and the resulting cost increase in agricultural production. For example, McPherson (1983) and Simmons (1987), claimed that land fragmentation may impose detrimental effects on agriculture in three ways (1) Creating inefficiency; (2) Hindering agricultural modernization and (3) Making it costly to modify its adverse effects by consolidation schemes. The relationship between the mean technical efficiency of farmers and the number of plots they cultivated is presented in Table 4. The table shows that maize farmers with several plots of land tend to be more efficient. Though, the mean values were very close (0.61 and 0.64).

Table 4. Technical efficiency and total number of plots cultivated

No of plots	Frequency	Mean TE	Group mean TE
1	6	0.61	
2	2	0.61	0.61
3	32	0.60	
4	34	0.67	
5	28	0.62	0.64
6	12	0.63	
Total	114	0.63	

Source: Field survey, 2006

Conclusion

Based on the objectives of the report, the following empirical conclusions are outstanding. In general, the results suggested that the sampled farmers were fairly technically efficient suggesting that there is the scope for increasing maize production if all maize farmers would adopt the technology and production techniques currently used by the most technically efficient farmer. Age, level of education, extension visit, farm mechanization, fertilizer usage, distance of farm from fertilizer market, and the technical efficiency of the farmers were the determinants of land fragmentation in the study area. In summary, the research work presented in this paper established a relationship between land fragmentation and maize farmers' productivity. Policy on land reform should be tailored towards the provision of more lands to the willing farmers. This will ensure that farmers who are not land owners can have access to adequate farmlands for cultivation for improved productivity.

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