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# Cereal Productivity in West Africa: A Panel Data Analysis

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## Abstract

The economic development of Africa, more than any other region, depends on development of the agricultural and agro-industrial sectors, which are fundamentally affected by productivity and land resources; this is particularly true of Sub-Saharan Africa. West African agriculture is characterized by small holdings, low capitalization and low yield per unit of land. It is against this backdrop that this study examined cereal productivity in West Africa, using panel data analysis. Panel data, which covers the period 1997-2013, was utilized for the study. The data for the study were obtained from the World Bank (World Development Indicators). STATA 11 econometric software was used for data analysis. Results revealed that rural population, arable land, land under cereal cultivation and numbers of tractor available for mechanization were the major determinants of cereal productivity. Hausman fixed-random test showed that Fixed Effect Model was better than the Random Effect Model and the Prob>$X^2$=0.0006<0.05 showed that the error terms were not correlated with the explanatory variables. It is therefore recommended that effort should be geared towards mechanizing West African agriculture in order to increase youth participation. Land tenure system should be reversed coupled with provision of tractor, improved seeds and other inputs in order to improve productivity, while order to obtain the best fit in panel data regression analysis, the use of fixed effect model is advocated.

## Keywords

Cereals, Hausman Test, Panel Data, Productivity, West Africa

## 1. Introduction

Cereals are those members of the grass family, the *Poeceace* grown for their characteristic fruit, the caryopsis, which have been the most important sources of world's food for the last 10,000 years (Ismaila, *et al.,* 2010). Wheat and barley are the oldest cultivated cereals. Their cultivation started in the fertile crescent of Mesopotamia some 10,000 years ago, this region now include parts of Turkey, Syria, Iraq and Iran (Onwueme and Sinha, 1991; Ismaila, *et al.,* 2010).

The major cereal crops in West Africa, for example, Nigeria are rice, maize, sorghum, wheat, pearl, millet, sugar cane and fonio millet with rice ranking as the sixth major crop in terms of the land area while sorghum account for 50% of the total cereal production and occupies about 45% of the total land area devoted to cereal production in Nigeria (National Extension Agricultural Research and Liaison Station (NEARLS, 1996; Ismaila, *et al.,* 2010).

Agriculture is the main stay of the West African economy. It involves small scale farmers scattered over wide expanse of land area, with small holding ranging from 0.5 to 3.0 hectare per farm land. It is characterized by rudimentary farm systems, low capitalization and low yield per hectare (Kolawale and Ojo, 2007; Ismaila, *et al.*, 2010).

West African agriculture is characterized by small holdings, low capitalization and low yield per unit of land. According to Ismaila *et al.,* (2010), agricultural production in most of African countries is also hampered by the predominance of fragile ecosystems and low inherited soil fertility. The declining fertility of Africa soils because of soil nutrients mining is a major cause of decreased cereals crop yield and per capital food production in the mid to long term, a key source of land degradation and environmental damage. Population pressures now force farmers to grow crop after crop "mining" or depleting the soil of nutrient while giving nothing back to the soil leading to low productivity.

Low farm productivity in Africa has many causes, including use of traditional crop varieties, increasingly depleted soils, shrinking plots of land, scarce and unreliable water supply, crop losses from pests and diseases, inequitable land-distribution patterns, inefficient and unfair markets, and poor agricultural and transportation infrastructures. Farms of less than 2 hectares in size account for 70-90% of all farms in many African countries and for the lion's share of food staples production (Spencer, 2002). Much of this food staples production is consumed on the farm, so only a small proportion of it enters the market. Nevertheless, small farms still account for the bulk of marketed surplus in many countries. In much of Africa even "large" farms rarely exceed 10 hectares and, though they sell larger shares of their staples production, they are still not major providers of the total marketed surplus.

There are good reasons for the dominance of small farms in food staples production in Africa. Farm mechanization has not been successful in most African countries despite some ambitious mechanization programs in the past. Difficulties in maintaining machines and obtaining spare parts and fuel have undermined many investments. Nor has animal draft power spread widely in many countries, being constrained by disease problems and seasonal shortages of feed and labor for animal maintenance (Pingali *et al.,* 1987). Without viable labor saving technologies, small farms with their better per hectare endowments of unpaid family labor retain a competitive edge over large farms. The prevailing land tenure and inheritance arrangements also make it difficult for farmers to consolidate land into larger holdings. In fact, far from consolidating land, African farms are getting progressively smaller (Jayne *et al.*, 2003).

On the average, African staples production has not kept pace with population growth, leading to increased import dependence, worsening poverty and malnutrition, and greater risk of famine in drought years. A large number of people in Africa are still affected by conflict and the lingering effects of the 2011/12 food crisis (FAO, 2013). Significant decreases in cereal production were recorded in several zones of West Africa, especially in Niger, Chad, Mali and Senegal. Furthermore, cereal production per capita has decreased by 14 percent in 2014 compared to 2012/2013 cropping season (FAO, 2014).

Interestingly however, the economic development of Africa, more than any other region, depends on development of the agricultural and agro-industry sectors, which are fundamentally affected by productivity and land resources; this is particularly true of Sub-Saharan Africa (Henao and Baanante, 2006; Ismaila *et al.,* 2010). By 2020, Africa is projected to import more than 60 million metric tonnes of cereal yearly to meet its demand (Henao and Baanante, 2006). Africa's food security situation has deteriorated significantly over the past two decades. Henao and Baanante, (2006) also stated that Africa has population growth of 3% yearly and the numbers of malnourished people has grown from about 88 million in 1970 to more than 200 million in 1991 – 2001.

The role of cereals to modern society is related to its importance as food crop throughout the world. In most parts of Asia and Africa, cereals products comprise 80% or more of the average diet, in central and western Europe, as much as 50% and in the United State, between 20 - 25% (Onwueme and Sinha, 1991; Ismaila, *et al.,* 2010).

Cereal crops are the major dietary energy supplier all over the world and particularly in West Africa, and provide significant amount of protein, minerals (potassium and calcium) and vitamins (vitamin A and C) (Idem and Showemimo, 2004). In most part of Africa, cereals supplies about 80% of the energy requirements. Cereals are consumed in a variety of forms, including pastes, noodles, cakes, breads, drinks etc. depending on the ethnic or religious affiliation. The bran, husk, plant parts and other residues are useful as animal feeds and in the culture of micro-organism. Wax syrup and gum are extracted from cereals for industrial purposes (Ismaila *et al.,* 2010).

In the light of the foregoing, the study of cereals productivity is germane and indispensable, as such cannot be overemphasized. Hence, the purpose of this study is to analyze the determinants of cereal productivity in West Africa using panel data regression analysis and to compare fixed and random effect panel data models with respect to the following hypothesis:

1. H0: Random effects model is the preferred model

Ha: Fixed effect model is the preferred model

2. H0: The unique errors (ui) are correlated with the explanatory variables

Ha: The unique errors (ui) are not correlated with the explanatory variables

## 2. Theoretical Framework and Literature Review

The economic theory of productivity measurement dates back to the work of Jan Tinbergen and Robert Solow who formulated productivity measures in a production function context and linked them to the analysis of economic growth. The field has developed considerably since, in particular following major contributions by Griliches, (1987) and Diewert, (2000). Today, the production theoretical approach to productivity measurement offers a consistent and well-founded approach (OECD, 2001).

Ozgur and Ahmet, (2009) in their study of the responsiveness of crop yield to producer prices using panel data analysis in Turkey found that the fixed effects model that controls for unobserved heterogeneity indicate that the relative prices of wheat to barley and wheat to fertilizer are important factors to determine productivity. Also the coefficients for the price of other crops as well as price of inputs, and average April and May rainfall were also found to be significant determinants of productivity.

Pandey *et al.,* (2006) investigated the role of upland rice in the farming systems of the northern uplands of Vietnam. Results showed that higher upland rice yields were associated with a lower proportion of total area planted to upland rice and a higher proportion planted to cash crops.

In another development, Poulton and Ndufa, (2005) found that within three subdivisions of Siaya and Vihiga districts in western Kenya, households that achieved higher maize yields in the long rains season had more diversified cropping patterns in the short rains season, controlling for farm size.

In a study of the responsiveness of crop yields to producer prices using balanced panel data by Bor and Bayaner, (2009) from 15 provinces in Turkey. Yield was decomposed into trend and random elements. A fixed effects regression was used to estimate the yield function in order to present the province effects. The rate of increase of the trend element was assumed to reflect changes in mean yield, resulting from the development of new technologies. The random element reflected the variation in the mean yield and was attributed to non-economic factors, such as weather. A variety of other variables that have impact on wheat yield were fuel prices, irrigation water prices, prices of seed and other substitutes such as sugar beet. The level of mechanization, the number and quality of tractors and harvesters and the change in the use of improved seeds are important indicators of technology.

Bayaner *et al.,* (1995) studied the differences in determinants of wheat yield under dry *versus* irrigated conditions using Nerlovian yield response model. The results from a fixed effects model that controls for unobserved heterogeneity indicated that the relative prices of wheat to barley and wheat to fertilizer were important factors to determine productivity. The coefficients for the price of other crops as well as price of inputs, and average April and May rainfall were also found to be significant determinants of productivity.

Bhattarai, (2001) considers irrigation development and societal income across 65 tropical countries from Asia, Africa and Latin America for the period of 1972 to 1991. Macro-economic policy and structural factors, like technical change in agricultural sector, change in cereals yield, structural change in the economy, agricultural share in GDP, value added in agriculture; and institutional characteristics of each country were also hypothesized to affect irrigation development at any moment. The relationship was modeled following standard panel-data analysis method. More specifically, fixed- effect weighted Generalized Least Square (GLS) technique with iteration was adopted to model the relationship between income and irrigation, the results were in principle equivalent to the results from Maximum likelihood estimation (MLE). A panel regression analysis was done each for global level combining three continents, and one model separately for Asia, to better isolate the regional impacts on variation of irrigation at any moment. Results showed strong evidence of an environmental Kuznets Curve (EKC) relationship between income and irrigation development trends in a global model combining all the tropical countries, and also for an Asia regional model. The global and regional (Asia) analyses were separately conducted to isolate some of the country or regional specific factors influencing irrigation decision at any moment. The results suggest that macroeconomic policy and institutional factors were equally important for explaining the irrigation development.

## 3. Methodology

Panel data, which covers the period 1997-2013, were utilized in this study. The data were obtained from the World Bank (World Development Indicators). The sample size and the period of this study were limited by the availability of data. Three West African countries, Mali, Nigeria and Togo were purposively selected for this study due to the volume of cereal production in these countries.

STATA 11 econometric software was used to analyze the data, using Panel Data Regression Model to capture both the cross sectional and time series data.

The Panel data Regression analysis was chosen instead of simple or multiple regression because it has the advantage of providing more informative data, more variability, less collinearity among variables, more degrees of freedom and efficiency (Gujarati and Porter, 2009; Jonathan and Victor, 2013). In addition, it is best suited to study 'dynamics of change and more complicated behavioral models, and has the capacity of enriching empirical analysis in ways that may not be possible for ordinary regression or multiple regression analysis (Jonathan and Victor, 2013).

*Model specification*

Following Kolapo *et al.,* (2012); Jonathan and Victor, (2013) the models for this study can be implicitly stated as follows:

$$CRLYD = f(ARABLND, LNDUCP, NTRACTS, RURALPOP) \quad (1)$$

Where: CRLYD = Cereal yield in Kg/ha

ARABLND = Arable land available for cereal production/ha/person

LNDUCP = Land Under cereal production/ha

NTRACTS = Number of tractor used/$Km^2$

RURALPOP = Rural population in number

Following Kolapo *et al.,* (2012); Gujarati and Porter, (2009) and Jonathan and Victor, (2013) the implicit fixed-effect within group model above can be econometrically and explicitly specified as follows:

$$CRLYDit = \beta 0it + \beta 1ARABLNDit + \beta 2LNDUCPit + \beta 3\,NTRACTS + \beta 4RURALPOP + Eit \quad (2)$$

Where: $\beta$ are the parameters to be estimated; i = 1, 2, and 3 cross-sectional unit; t = 1, 2, --- 16 year time period and E = within group error term.

Our choice of the fixed effects within-group model is based on the following observations by Gujarati and Porter, (2009):

a) Fixed effects estimators are consistent where a long panel is involved and are preferred to random effects estimators;
b) If the individual error components $E_i$ and one or more explanatory variables are correlated, then the random effects estimators are biased, whereas those obtained from fixed effects model are unbiased;
c) Even if it is assumed that the underlying model is pooled or random, the fixed effects estimators are always consistent.

The econometric and explicit form of the random-effect model was stated as follows:

$$CRLYDit = \beta 0it + \beta 1ARABLNDit + \beta 2LNDUCPit + \beta 3NTRACTS + \beta 4RURALPOP + Uit + Eit \quad (3)$$

Where: Uit = between group error term. All other variables are as defined in equation 2

Our choice of random effects on the other hand is based on the rationale according to Oscar, (2013) that unlike the fixed effects model, the variation across entities is assumed to be random and uncorrelated with the predictor or independent variables included in the model. In addition, an advantage of random effects is that you can include time invariant variables (i.e. gender). In the fixed effects model these variables are absorbed by the intercept. Random effects assume that the entity's error term is not correlated with the predictors which allows for time-invariant variables to play a role as explanatory variables. RE allows generalizing the inferences beyond the sample used in the model.

## 4. Results and Discussion

The parsimonious parameter estimates from our regression results are shown in tables 1 and 2 while the Hausman fixed-random test result is presented on table 3.

***Table 1.*** *Fixed-Effect within-group regression (cereal yield in Kg/ha as dependent variable).*

| Variable | Coefficient | Standard error | t-statistics | Probability |
|---|---|---|---|---|
| Arable Land | 329.4215* | 202.6726 | 1.63 | 0.108 |
| Land ucp | -0.000516*** | 0.0000136 | - 3.81 | 0.000 |
| No of tractors | -0.0233744 | 0.0231233 | - 1.01 | 0.315 |
| Rural pop | 0.0000475*** | 0.0000146 | 3.25 | 0.002 |
| Constant | 180.4691 | 235.2731 | 0.77 | 0.445 |

$R^2$ (overall) = 0.4005; No of observation = 96; F (4, 89) = 6.33; Prob. (F) = 0.0002
Source: Authors computation using STATA 11
*** Significant at 1%, *Significant at 10%

The results in table 1 shows that land under cereal cultivation (Landucp) and rural population (Ruralpop) are statistically significant at 1% level, while arable land available for cereal production is significant at 10% level. Rural population and arable land have a positive impact on the yield of cereals. This is in conformity with priory expectation and implies that the larger the arable land available for cultivation and the higher the rural population, the greater the quantity of cereal yield. This is in tandem with National Planning Commission (NPC, 2004) which opines that the bulk of agricultural production in West Africa takes place in rural areas.

Land under cereal cultivation has negative impact on cereal yield, this negates apriori expectation and could be due according to Breman, (2003); Taylor *et al.,* (2002) that technological change has transformed agriculture in the US, Europe and large parts of Asia and South America, but it has largely bypassed West Africa. That in this region, most farms are small, primarily cultivated with hand tools, planted with seeds with a low yield potential, using little or no chemical or organic fertilizer. The climate is arid or semi-arid, and there is inadequate infrastructure to provide water for irrigation. Consequently, most small farms are only able to attain yields which are less than one seventh of those regularly achieved in industrialized systems.

Numbers of tractors have negative but not significant coefficient and this implies that it has no significant effect on the output of cereal in West Africa and this could be due to the fact that agricultural production in West Africa is less mechanized.

$R^2$ of 0.4005 implies that 40.1% of the total variation in cereal yield was explained by the variables under consideration. While, Prob (F) = 0.0002 < 0.05 implies that on the whole, the model is fit and all the coefficients are significantly different from zero.

***Table 2.*** *Random-Effect GLS regression (cereal yield in kg/ha as dependent variable).*

| Variable | Coefficient | Standard error | z- statistics | Probability |
|---|---|---|---|---|
| Arable land | 82.40227 | 172.2286 | 0.48 | 0.632 |
| Landucp | -0.0000356*** | 0.0000134 | -2.66 | 0.008 |
| No of tractors | 0.285392** | 0.0140465 | 2.03 | 0.042 |
| Rural pop | 6.32 e-06** | 2.88 e-06 | 2.19 | 0.028 |
| Constant | 899.3315 | 87.59565 | 10.27 | 0.000 |

$R^2$ (overall) = 0.4363; No of observation = 96; Wald $X^2(4)$ = 70.44; Prob $(X^2)$ = 0.0000
Source: Authors computation using STATA 11
*** Significance at 1%, ** Significance at 5%

The RE GLS regression results were not quite different from the FE results discussed above, except that arable land has positive but not significant coefficient. This could mean that the land available for cereal cultivation has a positive effect on cereal yield, meaning that the lager the hectares of land available the greater the cereal production. $R^2$ of 0.4363 implies that 43.63% of the total variation in cereal yield was explained by changes within and between the entities of the independent variables. Prob$(X^2)$ = 0.0000 < 0.05 implies that on the whole, the model is fit and all the coefficients are also significantly different from zero.

***Table 3.*** *Hausman Fixed-Random Test.*

| | Coefficients | | | |
|---|---|---|---|---|
| | (b) | (B) | (b – B) | S.E |
| Variable | Fixed | Random | Difference | |
| Arablnd | 329.42 | 82.40 | 247.02 | 106.83 |
| Landucp | -0.0000516 | -0.0000356 | -0.0000159 | 1.92 e- 06 |
| Ruralpop | 0.0000475 | 6.32 e -06 | 0.0000412 | 0.0000143 |
| No of Tractor | -0.0233744 | 0.0285392 | -0.0519136 | 0.018368 |

b = consistent under H0 and Ha
B = Inconsistent under Ha, efficient under H0
$X^2$ (2) = (b –B) = 14.79
Prob> $X^2$ = 0.0006 (B is not positive definite)
Source: Authors computation using STATA 11

From table 3, the difference between FE and RE shows that arable land and rural population were positive while land under cereal cultivation and numbers of tractors were negative, thus, following the rule of thumb, Prob > $X^2$ = 0.0006< 0.05, we reject H0 and accept Ha.

The acceptance of H0 and rejection of Ha, implies that the fixed effect model is best and the unique errors (ui) were not correlated with the explanatory variables.

The unique error term which was not correlated with the explanatory variables could be due to the advantage of the RE model, according to Oscar, (2013) unlike the fixed effects model, the variation across entities is assumed to be random and uncorrelated with the predictor or independent variables included in the model. Random effects assume that the entity's error term is not correlated with the predictors which allows for time-invariant variables to play a role as explanatory variables.

In brevity, the variables which were used in proxy to measure cereal productivity were fair explanatory variables. While the FE model explained 40.1% of variation, the RE model explained 43.63% of variation in cereal yield. This means, though the models are slightly different, explained nearly the same variability with variant advantages. The implication for this is that panel data regression model is suited for productivity measurement compares to ordinary least squares (OLS) regression analysis.

## 5. Conclusion and Recommendations

It is not an exaggeration to say that cereal productivity in West Africa is still very low compare to its demand. Production is still majorly in the hands of the peasants scattered in different geographical areas who use crude implement. Operations are carried out on large expanse of land without corresponding yield increase. In order to improve productivity, mechanization should be encourage by various regional government coupled with provision of improved varieties of seeds, fertilizers and other improved technologies. Also, youth participation should be encouraged in order to improve productivity.

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