FORECASTING WHEAT PRODUCTION IN NIGERIA: A COMPARATIVE ANALYSIS OF GRAFTED POLYNOMIALS AND LINEAR FUNCTIONS.

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Abstract

Knowledge of future estimates of agricultural commodities is important in engendering strategies towards achievable food security programmes. Due to paucity of data and poor data culture in most third world countries, this exercise has been constrained to rely on trend models. Of the variants of trend model, the linear is the most used due to its simplicity. But agricultural time series do not always follow a linear trend; thus the use of this model could be misleading in some cases. Alternatives to linear trend models therefore need to be experimented with. This work compares production forecasts from linear function with those from a grafted function. It is based on wheat production data from 1965 to 2006 obtained from FAOSTAT. A linear-quadratic-linear mean (grafted) function was fitted. Results emanating from this function were compared with results obtained from a linear trend function. Results reveal that the grafted function provided more reliable estimates because it incorporated the major observed local trends in the forecasting framework. This finding lays empirical support to the superiority of grafted functions over linear models. Therefore, in using the trend function to forecast agricultural time series in Nigeria, efforts must be made to consider the peculiarities of trend segments in the series.

Keywords: Agricultural, commodities, forecast, grafted, functions

Introduction

Nigeria is finding itself more and more caught up in “wheat trap” in which most of its foods are made from wheat (Ayo, 2010). Presently, the domestic wheat demand is far more than the local production. It is on record that 90-95% of the wheat being consumed is imported from the United States of America (Falaki and Mohammed, 2011). This is paradoxical since the country has the capacity for to be self sufficient in Wheat production. Self sufficiency in food production is a long term goal of many nations. Reliable estimates are imperative for policy engendering towards self sufficiency in agricultural production.

Knowledge of future estimates of agricultural commodities and related series in agriculture is important for policy engendering but cannot be determined with certainty (Bivan *et al.*, 2013) due to paucity of data, poor information on the determinants of economic series and absence of reliable statistical routine (Philip, 1990). This has constrained forecasting attempts on agricultural commodities to rely on trend models.

Trend models include a number of variants, the most common of which is the linear trend model. It is also the simplest in application. It is however common knowledge that agricultural production series do not necessarily follow a linear trend (Bivan *et a.,*,2013). Thus estimates of agricultural production from linear trend models may not be reliable ingredients for long term policy engendering as it affects forecasting.

It is therefore worthwhile to attempt the use of other variants of the trend models. This work investigates the reliability of forecasts from a non-linear variant of the trend model using the linear model as control. This was undertaken by comparing the estimates from the two models with observed data.

Grafted polynomials involve segmenting the entire time frame into sections with similar local trends. The goal is to arrive at a function in which the peculiarities of data at particular sub periods in the entire series are captured. In Nigeria, (Bivan, *et al.*, 2013, Rahman, 2001, Philip, 1990) have, using different variants of the grafted model shown its superiority in forecasting agricultural output over the linear trend model. Bivan *et al*. (2013) applied the linear quadratic-linear form of the grafted polynomials to forecasting of sorghum in Nigeria using production data for 1970 to 2007 period. Their results relayed that the grafted model performed better. Similar conclusion was arrived at by (Rahman, 2001) who earlier adopted the same model for forecasting of maize in Nigeria. The application of a quadratic-quadratic-linear form of grafted polynomials by [Philip, 1990] to forecast maize production in Nigeria also led to similar conclusion. There is however no universality to as to which form of grafted functions to use (Nmadu, Yisa and Muhammed, 2009). What is advised is a trial of other variants to identify the function whose estimates comes closest to the observed data.

Materials and Method

Data: Secondary data were collected on wheat production in metric tons for the period 1965-2006 from Food and Agricultural Organization (FAO) statistical section- FAOSTAT 2013.

Method of Estimation: generally, the linear trend may be represented by

$Y= \alpha +\beta_1 t(1)$

Where: Y is the output of wheat in tons, α and β are the parameters to be estimated and t is the trend variable.

A graphical examination of the data generallyshowed 3 periods: 1965 to 1987, 1987 to 2000 and 2000 to 2006. Thus the following were proposed for the three segments.

$Y= \alpha_0 + \alpha_1 t, \ 1965\leq t\leq 1987$ (2)

$Y= \beta_0 + \beta_1 t + \beta_2 t^2$, for $1987\leq t\leq 1999$ (3)

And for the last segment

$Y= c_0 +c_1 t$, for $t>1999$ (4)

The $\alpha_{s,}$ β_s and c_s are the structural parameters to be estimated while t and Y are as earlier defined in equation 1.

It is customary to fit the terminal segment (equation 4) using a linear trend for the purpose of forecasting (Bivan *et al*.,2013, Rahman, 2001, Philip, 1990, Fuller, 1969). This is done in order to obtain a mean function which embodies all the key local trends observed in Y. According to Bivan *et*

al.(2013), this mean function to be derived should posses the following characteristics: it should be continuous, linear in structural parameters and differentiable at the joints of the pairs of the trend functions. That is, the following restrictions are required to hold.
$\alpha_0 + \alpha_1 k_1 = \beta_0 + \beta_1 k_1 + \beta_2 k_1^2$(5)
$\beta_0 + \beta_1 k_2 + \beta_2 k_2^2 = c_0 + c_1 k_2$(6)
$\alpha_{1=} \beta_{1+} 2\beta_1 k_1$(7)
$c_{1=} \beta_{1+} 2\beta_2 k_2$(8)
Where: the k_s are the joints of the segmented function: k_1=1987, k_2=1999. There are 7 structural parameters and 4 restrictions. This implies that only 3 parameters will be estimated from the mean function. We retain the coefficients (c_0, c_1 and β_2) in the last segment for subsequent estimation since our goal is to forecast (Bivan *et al*., 2013, Rahman, 2001).

The mean function was derived thus;
We start with equation 8 in order to make β_1 the subject of theequation. This leads to
$\beta_{1=} c_1 - 2\beta_2 k_2$ (9)
using (9), we eliminate β_1 from(7) to get an expression for α_1 as
$\alpha_{1=} c_1 - 2\beta_2(k_{2-} k_1)$ (10)
using (9) we also derive an expression for β_0 from (6) thus:
$\beta_0 = c_0 + \beta_2 k^2{}_2$(11)
Finally, we substitute β_1, α_1, andβ_0 into (5) to obtain an expression for α_0
$\alpha_0 = c_1 - 2\beta_2 k_2$ (12)
To get the mean function, α_0, α_1, β_0 andβ_1 were substituted for as they appear in (2-4). In the case of (2),$t <= k_1$, coefficients α_0, and α_1 weresubstituted for using (9) and (10). The resulting calculation yields
$Y = c_0 + c_1 t + \beta_2[k^2{}_2 - k^2{}_1 - 2(k_2 - k_1)t]$(13)
In the case of (3), $k_1 \le t \le k_2$, β_0 andβ_1 were substituted for using (11) and (12) to yield
$Y = c_0 + c_1 t + \beta_2(t - k_2)^2$(14)
In (4), $t > k_2$coefficient c_0 and c_1 were retained for forecasting purpose, it thus remains untouched.
Thus we have the mean functions
$Y = cX_0 + c_1 X_1 + \beta_2 X$(15)
Where,

$X_0=1$, for all t

$X_1=t$, for all t

$X_2= [k^2{}_2-k^2{}_1-2(k_2-k_1)t]$, for $t \leq k_1$

$=(t-k_2)^2$, for $k_1 \leq t \leq k_2$

= 0, otherwise

Equation 15, the mean function is now continuous given the set of restriction from (5)-(8).We used OLS to estimate (1) and (15) based on the observed data for wheat production from 1965 to 2006. To carry out the ex-post forecast, it is necessary to keep a part of the series (observed data) for comparison with the forecasted values from the different models tried. Hence, data for 2000 to 2006 were retained for the ex-post evaluation of the 2 equations estimated. The test of mean difference was employed in determining the respective level of differences between the forecasts from the two models and the observed data.

Results and Discussion

Results of OLS estimations for the two models are reported in Table 1. The structural parameters of the two models are significant. The grafted function performed better based on the coefficients of determination. These estimates were used in the ex post forecast for wheat production in Nigeria for the period 2000-2006 as shown in Table 2.

Table 1: Estimates of structural parameters for linear and grafted functions for wheat (1965-2006)

Variable	Linear equation	Grafted equation
X_1	1527.5 (t=4.54)	2214.24 (t=6.66)
X_2		52.72 (t=4.05)
Intercept	12930.31 (1.56)	-28887 (-2.31)
Adj R^2	0.32	0.51
Df	41	40

Source: Data analysis, 2015

Table 2 reports the numerical ex-post forecast for wheat in the last sub-period. Estimates from the grafted trend function are closer to the observed data for the period than those from the linear trend. This result confirms the superiority of grafted models in the events where observed data do not follow a linear trend. This is confirmed by the test of mean differences reported in Table 3.

Table 2: Ex-post forecasts of wheat production in Nigeria from 2002-2006

Year	Observed data	Forecast using Linear equation	Forecast using Grafted equation
2000	73000	67920.31	50825.64
2001	51000	69447.81	53039.88
2002	54000	70975.31	55254.12
2003	58000	72502.81	57468.36
2004	62000	74030.31	59682.60
2005	66000	75557.81	61896.84
2006	71000	77085.31	64111.08

Source: Data analysis, 2015

The test of mean difference between forecasted wheat production values of respective functions and the observed data for the 2000-2006 sub period reported in Table 3 reveals that while there is a significant difference between the observed data and forecast from the linear trend function at 1% level of error, the observed data and the forecasted values from the grafted function do not differ significantly at any reasonable error level.

Table 3: Test of mean difference between forecasts of respective functions and the observed data for the 2000-2006 sub period.

Variables	Mean value	Mean difference	z-value
Observed data	62142.86	-10359.96	-3.2
Linear estimate	70990.53		
Observed data	62142.86	4674.50	1.49
Grafted estimated	57468.36		

Source: Data analysis, 2015

CONCLUSION AND RECOMMENDATION

The forecasted values for wheat production using the grafted function are relatively closer to the observed data because the grafted function incorporated the major observed local trends in the forecasting framework. Where the requisite variables for forecasting are not available as is the case with Nigeria, this characteristic of the grafted model makes it more reliable in planning for future production in the agricultural sector based on the past periods.

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