Vector error correction modelling of Nigerian agricultural supply response

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Abstract

Undue taxing of the agriculture sector could constitute a disincentive to agricultural production in most low-income African countries where agriculture is being taxed for industrial development. There is an argument that the high level of taxation of agriculture in favour of industrialization is in part due to the underestimation of the supply response of the agricultural sector. This study tests the theoretical hypotheses that only price, non-price and natural disincentives respectively pose problems for agricultural growth.

Johansen's approach to co-integration analysis was employed to test these hypotheses using the time-series data from the Central Bank of Nigeria (CBN) statistical database. The long-run price elasticity of supply is 0.13 and capital shift supply 18 per cent. The implication of this is that much more in-depth research is needed to identify those factors that affect supply and to describe the effect of factors that shift supply in response to price incentives. This could provide valuable information for government in the use of appropriate policy measures and variables.

1. Introduction

Of the many contributions made by agriculture to countries' economies, one is of particular interest within the context of this paper. More specifically, agriculture in many countries serves as a source of resources for governments to foster industrialisation (World Bank, 1996; Krueger, Schiff & Valdes, 1992). This derives from Lewis' (1954) proposition of dual sectors in economic development. The proposition finds its application where agriculture is targeted for taxes through different direct and indirect measures, for example agricultural marketing policies, exchange rate regimes, and import substitution policies (Krueger *et al*, 1992). Between 1960 and 1985 most sub-

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Saharan African countries taxed their agricultural sectors and, according to Schiff and Valdes (1992), of the low- and medium-income countries of the world, sub-Saharan African countries taxed agriculture the most – up to 50 per cent in some cases.

However, little evidence exists that taxing agriculture to support industrial development is successful in enhancing economic growth. For instance, despite a long history of adopting this principle in Nigeria, there have been no consistent improvements in growth in either the agricultural or the industrial sector (Kwanashie, Ajilima & Garba, 1998).

Thiele (2000) is of the opinion that in order to determine the extent to which discrimination against agriculture hampers economic growth, one has to determine whether a dynamic response of agricultural supply can be expected if disincentives are removed. Cardenas (1994), who investigated the extent of government intervention in Côte d'Ivoire, argues that the high level of agricultural taxation in favour of industrialisation is in part due to the underestimation of the supply response of the agricultural sector.

In an earlier study by Bond (1983) of agricultural supply response to price incentives for some sub-Saharan African countries, relatively low supply responses were reported (0.34 for Ghana, 0.16 for Kenya, 0.13 for Côte d'Ivoire, 0.11 for Liberia, 0.14 for Madagascar, 0.54 for Senegal, 0.15 for Tanzania, 0.07 for Uganda, and 0.24 for Burkina Faso). These results were later called into question, since they ware based on Nerlove's (1958) restrictive assumptions. However, later studies that used less-restrictive models also reported low agricultural supply response to prices. Kwanashie *et al* (1998) reported 0.24 for Nigeria, while Thiele (2003) reported between 0.2 and 0.5 for some sub-Saharan countries, and Alemu, Oosthuizen and Van Schalkwyk (2003) reported 0.28 for teff in Ethiopia.

These reports then raised the proposition that aggregate price data do not accurately represent the incentives facing farmers. Kwanashie *et al* (1998) and McKay, Morrissey and Vaillant (1998) argue that the effect of other factors, such as lack of public reinvestment and credit facilities, should also be taken into account when estimating agricultural supply response, since aggregate price data alone do not accurately represent the incentives facing farmers, and hence could lead to an underestimation of agricultural supply response.

The focus in this study is to examine the long-run relative importance of not only price, but also government investment, in maintaining/developing agricultural capital and credit incentives for agricultural supply response in

Nigeria. This study is motivated by using a less-restrictive approach to supply response estimation in order to test the following hypotheses as raised by Thiele (2000) from the studies of Krueger *et al* (1992), Platteau (1996) and Bloom and Sachs (1998):

i. Appropriate (direct and indirect) price incentives alone encourage agricultural development;

ii. Non-price factors such as unreliable rural infrastructure and limited access to credit are the main bottlenecks for agricultural development; and

iii. Natural conditions, such as low soil fertility and low and irregular rainfall are banes to agricultural growth.

Those favouring industrial growth argue that the inability of agriculture to respond favourably to policy instruments and programmes aimed at revitalising agriculture is due mainly to the third hypothesis mentioned above, whilst the other two hypotheses hold minor significance.

Section 2 presents an overview of the problems facing agricultural growth in Nigeria. Section 3 presents the approaches to measuring aggregate supply response. Section 4 gives the empirical results of this study, while section 5 presents the summary and conclusion.

2. State and problems of agricultural policy in Nigeria

Nigeria has experienced a decline in agricultural production since the late 1960s, despite the fact that different policy regimes and programmes have been implemented to improve productivity in the Nigerian agricultural sector. Policy regimes have included those focusing on economic diversification, national self-reliance, structural adjustment, economic consolidation and expansion, national food security, etc. (Vision 2010 Committee, 1997). In addition, various programmes were implemented aimed directly at improving agricultural production and investment (e.g. irrigation projects) largely to increase agricultural exports. These efforts, however, have not transformed peasant agriculture in Nigeria into a viable commercial agriculture sector. Bad terms of trade in the food market have been a resultant consequence (African Development Bank, 1998).

Planning objectives have often been vague or broadly stated (Ijere, 1983). The relatively low level of agricultural growth and the poor supply response to policy instruments and programmes may in part be due to a lack of understanding of the level of price-supply response and other factors that affect agriculture.

3. Measuring agricultural supply response

Nerlove's (1958) partial adjustment model is an earlier version of an econometric approach used in measuring agricultural supply response for a single commodity. This model is used to capture agricultural supply response to price incentives. The general static supply function has the form:

$$Y_t = c + \beta P_{t-1} + \gamma T + \vartheta_t \quad (1)$$

where Y_t is the expected long-run equilibrium output level at time t; c is the constant term; β is the long-run supply response; P_{t-1} is the output price at time t-1; γ is the coefficient of linear deterministic time trend, T and υ_t is the independently normally distributed error . The dynamic adjustment supply response equation is presented by equation 2:

$$Y_t^* - Y_{t-1}^* = \lambda(Y_t - Y_{t-1}^*), \qquad 0 < \lambda \le 1 \quad (2)$$

where Y_t^* is the expected output level at time t, and λ is the coefficient of expectation about price or elasticity if variables are in logarithm (Nerlove, 1958). Therefore, substituting equation 1 into 2 gives

$$Y_t^* = \lambda c + \lambda\beta P_{t-1} + (1-\lambda)Y_{t-1}^* + \lambda\gamma T + \lambda\vartheta_t \quad (3)$$

where $\lambda\beta$ captures the short-run price elasticity. Nerlove proposes that if producers have "static" expectations and if supply depends on expected "normal" prices or prices of the preceding year, then the coefficient of expectation, namely λ in equation (2), is 1. If this is the case producers do not immediately adjust their production decisions to changes in prices observed in period t, such that

$$Y_t = Y_t^* = c + \beta P_{t-1} \quad (4)$$

Even when λ is less than 1, the fluctuation in expected output level is less than the fluctuation in the observed output level such that the actual change in output level between period t and t-1 is only a fraction of the change required to achieve the expected output level. In that case the only condition for observing significant differences between short- and long-run elasticities is the introduction of non-static assumptions.

Therefore, Nerlove's proposition is flawed, since studies that have employed it have mostly found low values, or even zero long-run price elasticity of agricultural supply. The method assumes that the difference between current and long-run planned outputs is eliminated, i.e. it assumes that farmers are not forward looking in their production decisions. It also lacks the capacity to measure the effect of non-price factors such as rural infrastructure and credit.

Due to these limitations the Error Correction Model (ECM) with co-integration analysis is favoured over the Nerlove method. It not only overcomes the restrictive dynamic specification of the Nerlove method, but also captures the forward-looking behaviour of producers optimising their production in dynamic situations. ECM is used to analyse non-stationary time series that are known to be co-integrated. It assumes co-movement of the variables in the long run. The general ECM is of the form:

$$\Delta Y_t = c + \sum_k \alpha_k \Delta Y_{t-n} + \lambda(Y_{t-1} - \sum_j \beta_j X_{jt-n}) + \gamma T + \vartheta_t \tag{5}$$

where Δ is the deference operator such that $\Delta Y_t = Y_t - Y_{t-1}$, α_j and β_j are respectively vectors of short-run and long-run supply elasticities with respect to factor j. Ys are the (assumed) co-integrated time series variables (including pervious supply levels Y_{t-n} and explanatory variables X_{t-n}).

Co-integration analysis can be carried out with the Johansen or Engle-Granger test approaches. The conditions and general characteristics of the approaches are discussed in the next sections.

3.1 Engle-Granger approach to co-integration analysis

The Engle-Granger test for co-integration (Engle & Granger, 1987) involves estimating a static Ordinary Least Square (OLS) model where all variables enter at levels. Usually the OLS of this equation shows a high adjusted R^2 with a very low Durbin-Watson statistic, which indicates significant evidence of serial correlation in the residual, υ_t. To test for the co-integration of the series, the residual υ_t is expected to be stationary, i.e. having a unit root. In the "spurious" OLS regression, the t-statistics cannot be used to test hypothesis, because the variables are not stationary in levels. Subsequently the Augmented Dicky-Fuller (ADF) regression of the form

$$\Delta\vartheta_t = \delta_o\vartheta_t + \sum_{i=1}^{k}\delta_i\Delta\vartheta_{t-k} \tag{6}$$

is fitted to test for stationarity of the residual ϑ_t of equation (1). If there is evidence of unit root, i.e. the residual is stationary, then there is evidence of co-integration of the time series in equation (5). k is an arbitrarily chosen lagged period until the residual is found stationary when δ_i is significantly different from zero. Then β in equation (5), which is the parameter estimate of long-run supply elasticity, may be interpreted as the co-integrating parameter from linear combination of the series. However, error correction representation may result from this co-integration. This error is subsequently corrected by using the residual ϑ_t to estimate an ECM of the form:

$$\Delta Y_t = c + \alpha\Delta X_{t-n} + \lambda\vartheta_t \tag{7}$$

Banerjee, Dolado, Hendry and Smith (1986) critique the Engle-Granger approach because the estimate of the co-integrating parameter from the static regression equation (1) could be subject to small sample bias. They argue that this can be overcome by estimating the ECM in dynamic form by replacing residual υ_t with the lagged variables (Y_{t-1} – X_{t-1}) and X_{t-1} resulting in the following unrestricted regression:

$$\Delta Y_t = c + \alpha_{t-n}\Delta X_{t-n} + \lambda_{1n}(Y_{t-n} - \beta X_{t-n}) + \lambda_{2n}X_{t-n} \tag{8}$$

where α is the short-run elasticity of supply and λ_2 is the dynamic adjustment of supply. λ_1 is the coefficient of the error/equilibrium correction term of the co-integration equation, which presents the period to adjust to the long-run equilibrium. λ_1 must be negative and significantly different from zero (Hwang, 2002). Being negative implies that if there is a deviation from the current and long-run levels; there would be an adjustment back to the long-run equilibrium in subsequent periods to eliminate the disequilibrium.

If β is significant, the ECM captures the speculative behaviour of producers, otherwise the ECM reduces to the Nerlove partial adjustment model. It should be noted that while static co-integration regression predicts the level of supply, the error correction regression predicts the changes so that the variation in the supply is necessarily higher. The new, corrected co-integration parameter estimate (long-run elasticity), β^*, is computed as (Guarda, 1996):

$$\beta^* = 1 - \frac{\lambda_{2n}}{\lambda_{1n}} \textbf{ or } \frac{\lambda_{2n}}{\lambda_{1n}} \text{ if the fraction is negative} \tag{9}$$

The Engle-Granger approach to co-integration is suited to bivariate relationships.

3.2 Johansen approach to co-integration analysis

The Johansen (1988) test of co-integration involves estimating Vector Error Correction Models (VECM) of the form:

$$\Delta Y_t = c + \sum_j \alpha_j \Delta Y_{t-1} + \delta D_t + \gamma T + \lambda \varepsilon_{t-1} + \vartheta_t \tag{10}$$

where $\varepsilon_{t-1} = \ln Y_{t-1} - \sum_j \beta_j Y_{jt-1}$ (error/equilibrium correction term).

D_t is a vector of stationary exogenous variables; δ is vector of parameters of exogenous variables; λ is the coefficient of error correction term ε_{t-1}.

The Johansen method provides two likelihood ratio tests, namely the Trace and the Maximum Eigen Value statistic tests, which are used to determine the number of co-integrating equations given by the co-integration rank r. A co-integration equation is the long-run equation of co-integrated series. The Trace statistic tests the null hypothesis of *r* co-integrating relations against the alternative of *k* co-integrating relations, where k is the number of endogenous variables for *r* = 0, 1,..., *k* – 1. The Maximum Eigen Value statistic tests the null hypothesis of *r* co-integrating vectors against the alternative of *r* + 1 co-integrating vectors.

When the co-integration rank r is equal to 1, the Johansen single equation dynamic modelling and the Engle-Granger approaches are both valid. When r equals 1, the normalisation restriction for the parameters produces a unique estimate of what the economic theory suggests (Golinelli, 2003). However, when there is more than one co-integration equation the Johansen approach to co-integration analysis is preferred to the Engle-Granger approach (Kremers, Ericsson & Dolado, 1992; Thiele, 2003).

4. Empirical results from Nigeria

4.1 Data source

The data for this study were sourced from the Central Bank of Nigeria (CBN) Statistical Bulletin (Central Bank of Nigeria 2003). More consistent data were available from 1978 to 2003. The time series that were readily available and used for this study included:

1. Variable Y is the aggregate agricultural production index.

2. Variable P is the index of average world prices of Nigeria's agricultural commodities (in Naira per ton) as a price variable. Variable P was adjusted by all-items consumer price index.

Among other variables that could shift the supply response, the following variables were considered due to data inadequacy:

3. Variable K is the total value (in Naira) of the government capital expenditure that goes to the agricultural sector to augment the capital stock available for agricultural production in the current period. This variable is to serve as a proxy for the accumulation of capital stock available for agricultural production.

4. Variable C is the total value (in Naira) of agricultural loans granted by the government's Agricultural Credit Guarantee Scheme Fund. This is to represent the credit facilities available to the producers.

Y, P, K and C were logged. The variable T, technology, was modelled with the series as represented by the time variable serving as a proxy for the impact of technology change on output, i.e. to capture technical progress, productivity, high-yielding varieties, etc.

The underlying assumption is that the price and loan incentives affect the level of technology implementation in production among the producers. A Cobb-Douglass function was assumed, among other possible production technologies, to represent the production model as follows:

$$\ln Y_t = \alpha_o + \alpha_1 \ln P_t + \alpha_2 \ln K_t + \alpha_3 \ln C_t + \gamma T + \vartheta_t \quad (11)$$

The VECM was specified as follows:

$$\Delta \ln Y_t = c + \alpha_o \Delta \ln P_{t-1} + \alpha_1 \Delta \ln K_{t-1} + \alpha_2 \Delta \ln C_{t-1} + \gamma T + \lambda \varepsilon_{t-1} + \vartheta_t \quad (12)$$

where $\varepsilon_{t-1} = \ln Y_{t-1} - \beta_1 \ln P_{t-1} - \beta_2 \ln K_{t-1} - \beta_3 \ln C_{t-1}$

5. Results and discussion

5.1 ADF test of unit roots

Table 1 shows the ADF unit root test. Only K and C were stationary at levels. The null hypothesis of non-stationarity was rejected. Y and P had 1 unit root. The null hypothesis of non-stationarity was accepted. At first difference, the ADF test statistics were larger than the MacKinnon critical values of all the series at 1% levels of significance. By economic theory, these series (at levels) are expected to have a long-run economic relationship. Therefore, the Johansen test of co-integration was performed using EViews statistical software to determine whether a stable long-run relationship exists between the series at levels and at first deference (Johansen & Juselius, 1990; Gonzalo, 1994; Johansen, 1995). The lag length was determined using Akaike Information Criteria (AIC) and Schawrz Criteria (SC), but lags were not deleted if their exclusion introduced serial correlation.

Table 1: Results of ADF test (Ho: there is unit root)

Variables	Test statistic at levels	Inference	Test statistic at first difference	Constant term, linear trend and lag level	Inference
Y_t	-3.13	Accept H_o	-2.92****	Constant and 1 lag	Reject H_o
P_t	-1.61	Accept H_o	-4.98****	1 lag	Reject H_o
K_t	-3.74****	Reject H_o	-3.85****	1 lag	Reject H_o
C_t	-2.06***	Reject H_o	-5.12****	1 lag	Reject H_o

****significantly different from 0 at 1% level; *** significantly different from 0 at 5% level

5.2 Johansen test of co-integration

From Table 2, the trace statistic shows that only the null hypothesis of at most one co-integration equation cannot be rejected at 10% significant level with the assumption of quadratic deterministic trend in the series. This assumption is buttressed by the trend in series (see Appendix A). The statistical evidence of co-integration supports the theory of long-run equilibrium between supply, price, capital and credit facilities. It also supports one co-integration relation between the series and hence the decision regarding one co-integration equation. The Johansen co-integration approach was adopted, as there was evidence of one co-integrating equation from the Johansen co-integration test (see Table 2). The results of both the short-run and long-run parameters are reported in the section below.

Table 2: Johansen co-integration test

Hypothesis	Trace statistic	Eigen value	10% critical value	Decision
H_o: r = 0; H_1: r > 0	53.57**	0.6015	53.12	Indicate one co-integration equation
H_o: r = 1; H_1: r > 1	31.49	0.5261	41.07	
H_o: r = 2; H_1: r > 2	13.57	0.3880	24.6	
H_o: r = 3; H_1: r > 3	1.78	0.0716	12.97	

** significantly different from 0 at 10% level

5.3 Long-run supply response

The normalised equation shows signs that are consistent with the agricultural supply models for price and capital. The long-run supply response to accumulated agricultural capital is 0.18 and statistically significant at 1% level. This implies that capital does not shift supply appreciably. This may imply that the capital investment in agriculture is low and/or that there is low capital utilisation in the agriculture sector in Nigeria.

The long-run price supply elasticity is 0.13 and statistically significant at 15% level. This is as relatively low as the results obtained by most studies that used other methodologies of estimation. However, credit facility does not show a consistent sign with supply or production theory.

Table 3: Normalised co-integrating equation showing long-run elasticity

Variables/Terms	Constant	$\ln P_{t-1}$	$\ln K_{t-1}$	$\ln C_{t-1}$	@Trend (1978)
Estimates	-5.3805	0.1285	0.1840	-0.1588	0.07469
t-statistic	-	1.52*	4.18****	-3.09****	-

**** significantly different from 0 at 1% level; * significantly different from 0 at 15% level

The error correction term is significantly different from zero at 5% level with an expected negative sign. This confirms the long-run equilibrium between the series. However, it shows that about 15% proportion of disequilibrium in Y in one period is corrected in the next period.

The short-run effect of capital and credit facilities and time trend are not significant. However, the short-run effect of price has a negative sign and is significant at 5% level. This may confirm the assumption that the short-run supply response is low and that the use of primary factors that account for about 70 to 85 percent of the cost of agricultural production in developing countries cannot be changed in the short run (Binswanger, 1993; Thiele, 2000).

However, the coefficient of error correction term gives the expected negative sign and is statistically significant (1%). The model explains about 48% of variability in supply.

Table 4: Error correction estimates showing short-run relationship

Variables/ Terms	ΔlnY_{t-1}	ΔlnP_{t-1}	ΔlnL_{t-1}	ΔlnK_{t-1}	Constant	@Trend (1978)	Error correct-ion term	R^2	F
Estimates t-statistic	0.1653 0.76	-0.0475 -2.09***	-0.0116 -1.05	0.0033 0.31	-0.0516 -2.69***	0.0007 0.68	-0.1499 -2.16***	0.48	5.57

*** significantly different from 0 at 5% level

Although this study employed less-restrictive models, it confirms the results reported by Kwanashie *et al* (1998). Kwanashie *et al* (1998) used two-stage least square and seemingly unrelated regression methods to estimate Nigerian agricultural supply response to price and other incentives. The reported long-run price elasticity was as low as 0.24 for the aggregate crop variable, and there was a response to capital expenditure.

Agricultural capital's low effect on supply may result from persistently low capacity utilisation in capital and intensive agricultural projects in Nigeria. The low capacity utilisation might not derive only from "poor" prices, as previous studies have shown that most farmers were unable to easily acquire some intensification technologies, such as inorganic fertilisers, due to scarcity and poor distribution (Diels, Sanginga, Iwuafor, Tossah, Aihou, Lyasse, Vanlauwe & Merckx, 2002; Bamire & Manyong, 2003). In addition some irrigation and farm settlement schemes have not been self-sustaining owing to some socio-economic and institutional problems in Nigeria (Fabiyi & Idowu, 1997; Thaboni, 1997; African Development Bank, 1998; Olubode, 2003).

Natural forces are evident in the characteristic low level and erratic rainfall patterns that render the inherently phosphorous-deficient soil acidic in the northern Guinean savannah of West Africa, especially in Nigeria. Kwanashie *et al* (1998) reported that food crops respond sensitively to agro-climatic conditions in Nigeria. According to Diels *et al* (2002) the acidic condition of the soil is being aggravated through small-scale farmers' continuous use of land with an often low rate of inorganic fertilisation.

6. Summary and conclusion

From this study, the relatively low price elasticity observed may confirm that in most developing sub-Saharan African countries, including Nigeria, agriculture is still less responsive to price incentives. It is also interesting to note that capital and credit that could shift supply have a relatively insignificant effect on the shifting of supply. This bears relevance to the assumption of Thiele (2000) that the amount of technology adopted by farmers depends not only on the level of technology available, but also on the price incentives and constraints that weather conditions may pose for farmers. The same assumption may hold for the effect of credit on supply.

On the other hand, if price rises significantly, but there is insufficient machinery and credit to increase supply in response to the "good" price, the price response might remain low. Also, for a nation like Nigeria, where importation is increasing, there is a tendency for the price of agricultural products to drop, which consequently reduces domestic production. Invariably this in turn may discourage commercial production.

Due to data constraints, this study could not consider all factors that impact on agricultural supply. It is therefore fair to conclude and postulate another hypothesis, namely that distorted prices, poor technology development, low credit facilities and other factors are the bane of agricultural growth in Nigeria. The implication of this is that much more in-depth research is needed to identify those factors that affect supply and to describe the effect of factors that shift supply on the response to price incentives. This could provide valuable information for government in its use of appropriate policy measures and variables.

In-depth research to determine/identify other factors affecting the agricultural supply response could provide valuable information in terms of foreign aid programmes, government policy, and the design of programmes aimed at fostering economic growth where agriculture is the mainstay of the economy.

One of the limitations of this study was lack of sufficient data, which restricted the study to a relatively high level of aggregation of agricultural production. For this reason, weather conditions and structural breaks were not considered (although the trends in the series do not suggest structural breaks). Also, the time series is relatively small and this may have impacted particularly on co-integration. All these factors may lead to underestimation of aggregate supply response. Any of these limitations may explain the non-significance of some of the variables.

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References

African Development Bank (1998). *Survey of the main production sectors*. African Development Bank Report, New York: Oxford University Press Inc, p 229.

Alemu ZG, Oosthuizen LK & Van Schalkwyk HD (2003). Grain-supply response in Ethiopia: An error correction approach. *Agrekon* 42(4):389-404.

Bamire AS & Manyong V (2003). Profitability of intensification technologies among smallholder maize farmers in the forest savanna transition zone of Nigeria. *Agriculture, Ecosystem and Environment* 100(2):111-118.

Banerjee A, Dolado J, Hendry D & Smith G (1986). Exploring equilibrium relationships in econometrics though static moles: Some Monte Carlo evidence. *Oxford Bulletin of Economics and Statistics* 48(3):253-276.

Binswanger HP (1993). *Determinants of agricultural supply and adjustment policies.* In: Heidhues F & Knerr B (eds), Proceedings of the European Association of Agricultural Economists' 29th Seminar titled Food and Agricultural Policies under Structural Adjustment. Frankfurt am Main: Lang, p 107-136.

Bond ME (1983). *Agricultural response to prices in sub-Saharan African countries.* IMF Staff Papers No 30: 703-726.

Bloom DE & Sachs J (1998). Geography, demography and economic growth in Africa. *Brookings Papers on Economic Activity* 2:207-273.

Central Bank of Nigeria (CBN) (2003). Public finance and price statistics. *Statistical Bulletin* 13(Parts B & C):86-171.

Cardenas M (1994). Stabilization and redistribution of coffee revenues: A political economy model of commodity marketing boards. *Journal of Development Economics* 44:351-380.

Diels J, Sanginga N, Iwuafor ENO, Tossah BK, Aihou K, Lyasse O, Vanlauwe B & Merckx R (2002). *Balanced nutrient management systems in West African savannah soils.* Working Material Report of the 2nd Research Co-ordination Meeting of the Co-ordinated Research Project, Brasilia, Brazil, 11-15 March 2002, p 56.

Engle RF & Granger CWJ (1987). Co-integration and error correction: Representation, estimation and testing. *Econometrica* 55(2):251-276.

Fabiyi YL (1996). *Key issues in agricultural planning in Nigeria*. Paper presented at the Fifth National Workshop for Agricultural Planners, Green Springs Hotel, Ibadan, 22 September - 4 October 1996.

Food and Agriculture Organization (FAO) (1984). *Development in food security: The State of Food and Agriculture.* Rome: Food and Agriculture Organization of the United Nations, p 4-16.

Golinelli R (2003). *Lectures on modelling non-stationary time series*. CIDE's PhD Lectures, Bertinoro (FO), September 2003, p 75.

Gonzalo CWJ (1994). Five alternative methods of estimating long-run equilibrium relationships. *Journal of Econometrics* 60:203-233.

Guarda P (1996). *A consumption function for Luxembourg: Estimating an error-correction model*. Mod-L2 Project Report [Online], p 29. Available from: http://www.crpcu.lu/projets/modl.html.

Hwang J (2002). The demand for money in Korea: Evidence from the cointegration test. *Int'l advances in Econs. Res.* 8(3):188-195.

Ijere MO (1983). *Readings in Nigerian agricultural policy and planning*. Port Harcourt, Nigeria.

Johansen S (1988). Statistical analysis of co-integration vectors. *Journal of Economic Dynamics and Control* 12:231-254.

Johansen S (1995). *Likelihood-based inference in cointegrated vector autoregressive models.* Oxford: Oxford University Press.

Johansen S & Juselius K (1990). Maximum likelihood estimation and inferences on cointegration – with applications to the demand for money. *Oxford Bulletin of Economics and Statistics* 52:169–210.

Kremers J, Ericsson N & Dolado J (1992). The power of co-integration tests. *Oxford Bulletin of Economics and Statistics* 54(3):325-348.

Krueger AO, Schiff M & Valdes A (1992). *The political economy of agricultural pricing policies: A World Bank comparative study*. Baltimore: Johns Hopkins University Press.

Kwanashie M, Ajilima I & Garba A (1998). *The Nigerian economy: Response of agriculture to adjustment policies*. AERC Research Paper 78, ISBN 9966-900-66-7, p 58.

Lewis AW (1954). Economic development with unlimited supplies of labour. *Manchester School of Economic and Social Studies* 22(2):139-191.

McKay A, Morrissey O & Vaillant C (1998). *Aggregate export and food crop supply response in Tanzania: DFID – TERP.* Credit Discussion Paper 4, p 22.

Nerlove M (1958). Distributed lags and estimation of long-run supply and demand elasticities: Theoretical considerations. *Journal of Farm Economics*, 40(2):301-311.

Olubode OO (2003). *Socio-economic performance of Ogun-Oshun River Basin and Rural Development Authority's farmer-based irrigation projects.* Unpublished MSc Research Thesis, Department of Agricultural Economics, Obafemi Awolowo University, Ile-Ife, Nigeria, p 110.

Platteau JP (1996). Physical infrastructure as a constraint on agricultural growth: The case of sub-Saharan Africa. *Oxford Development Studies* 24:189-219.

Thaboni M (1997). Formal water market: Why, when and how to introduce tradable water rights. *World Bank Research Observer* 12(2):161-179.

Thiele R (2000). *Estimating the aggregate agricultural supply response: A survey of techniques and results for developing countries.* Kiel Institute of World Economics Working Paper No 1016, p 22.

Thiele R (2003). *Price incentives, non-price factors and agricultural production in sub-Saharan Africa: A cointegration analysis.* Contributed paper selected for presentation at the 25th International Conference of Agricultural Economists, 16-22 August 2003, Durban, South Africa, p 16.

Vision 2010 Committee (1997). *Main Report of the Vision 2010 Committee.* Abuja: Economic Affairs Office, Presidency.

World Bank (1996). *Nigeria poverty in the midst of plenty: The challenge of growth with inclusion.* A World Bank Poverty Assessment Report No 14733-UNKI.

Appendix A

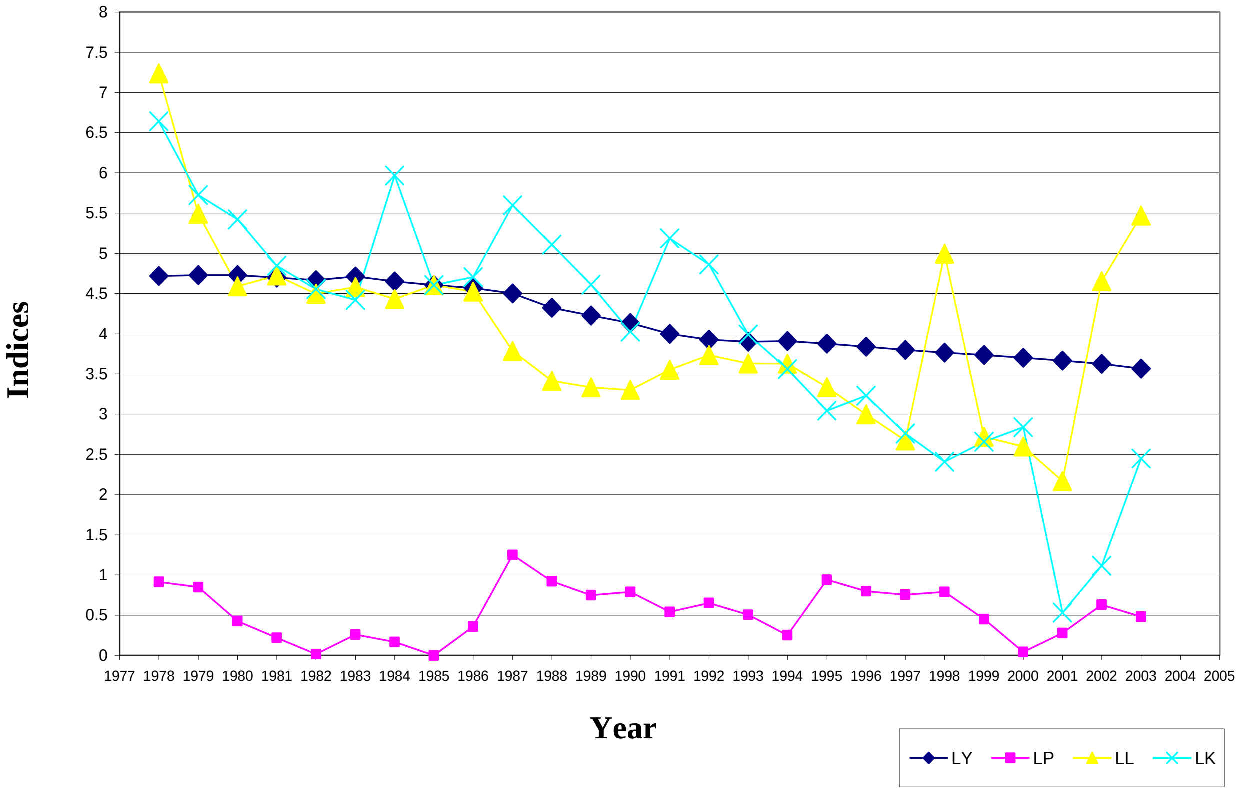

Figure 1: Y, P, C and K (in logarithms)