Maize Supply Response to Changes in Real Prices in Nigeria:
A Vector Error Correction Approach

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Abstract: The response of farmers to price and non-price incentives in Sub-Saharan African (SSA) agriculture has received wide attention in the past because of the raging controversy among economists as to whether farmers in SSA are responsive to economic incentives and to what degree. Apart from this, there has been the issue of whether farmers' response to prices depends more or less on the nature of the price variable (nominal or real) used. This study addresses these concerns using maize supply responsiveness in Nigeria as a case in point. It compares the current results with a previous study that used nominal prices. Results show that the response of maize farmers to real maize price is very high, with an estimated elasticity of 2.5259 in the short-run and 1.5038 in the long-run. These figures are close to 2.7588 and 1.9925 in the short- and long-run, respectively obtained from the previous study. By the same token, the response of maize supply, to the real price of rice is equally high, with a cross price elasticity of -4.6414 in the short-run and -2.5798 in the long-run, which are clearly larger than -2.6771 and -1.8033 in the short and long-run correspondingly obtained with nominal prices. The speed of adjustment of the real prices of maize and rice from short-run disequilibria to changes in maize supply in an effort to attain long-run equilibrium is 240.09% within one year, signalling an overreaction of maize farmers to changes in real prices of maize in the short-run. Among other interventions, the paper recommends a policy package that would boost the demand for maize by stimulating its utilization by small and medium enterprises and large scale industries, while at the same time reducing inflation, since farmers' adjustment to short-run changes in price is faster with increase in real prices than nominal prices. Moreover, investment in high-yielding and early-maturing hybrids of maize and rice should be furthered to take care of the problem of substitution in the production of maize in relation to rice.

Key words: Maize, speed of adjustment, cointegration, real price, supply response

INTRODUCTION

Agricultural supply response has remained a central issue in economic development, especially in developing countries in sub-Saharan Africa which major feature is a rudimentary agricultural sector characterised by structural rigidities, low private investment, a large government involvement and regulation, weak support services and institutional framework as well as policy instability. These inherent features have collaborated with other macroeconomic imbalances in these countries to breed severe economic misfortunes that eventually led the countries on the path of economic reform which took centre-stage in the economies in the wake of the 1980 decade. In Nigeria, economic reform which was embarked upon as the Structural Adjustment Programme (SAP) in 1986 had, among others, one major objective for the agricultural sector: discouraging the importation of those commodities that the country has comparative advantage in their production especially those in which huge amounts were being spent on their importation (Agricultural Policy for Nigeria, 1988; Ojo and Akanji, 1996). One of such commodities was maize.

Maize production has largely been influenced by government policies given its importance as a major staple food for humans and source of feed for livestock. For instance, in the 1979 budget speech by the then Head of State, General Olusegun Obasanjo, maize imports from the United States of America were restricted due to the huge amounts that were involved in the importation and because the country can produce maize in sufficient quantity. Nevertheless, barely four months later the policy was rescinded due to a severe scarcity of the grain in the country. This policy of restriction of maize imports coincided with the era of fixing of Guaranteed Minimum Prices for scheduled crops, which also included maize.

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These courses of action were all aimed at increasing domestic production of the crop, but because of the structural problems earlier outlined the expected response by farmers would not have been achieved thus making the government to reverse the policy.

In 1985, the Nigerian government adopted an import substitution policy, which banned the importation of maize, principally, among other crops and food items. This inward-looking strategy was also aimed at providing price and non-price incentives for producers to increase domestic production by way of supply responsiveness. The policy was retained in 1986 when the SAP was introduced. In fact, the ban on maize importation has been a major policy of government on maize because of its implication on humans and the poultry sub-sector, which has suffered rising costs of feed input and consequently rising prices of poultry products for over two decades. Interestingly, since the ban on importation of maize, the country has depended mainly on domestic production for both food and industrial use. Particularly, it has been argued that the ban on importation of maize by the Federal Government since 1986 has greatly expanded overall demand for maize as well as its uses. This is more so because growth in maize utilization has been driven by the rapidly increasing demand for maize as livestock feed and for industrial food and non-food products, as direct food uses of maize tend to decline as per capita income, milk, meat and egg consumption increases. According to Shaib *et al.* (1997) the projected demand for maize in Nigeria from 2004 to 2009 will be more than the production during the period unless a growth rate of greater than 3.2% (average annual growth rate of demand) is attained. Adepoju and Ogungbile (2006) have observed that a major problem being faced by Nigerian maize processors and users is inadequate supply of maize in commercial quantities to meet their requirements aside the dearth of information on the quality characteristics of available varieties. Apart from all these, there has been controversy as to whether farmers respond more or less to nominal or real prices.

In view of the foregoing concerns, the questions of interest in this study are:

- Have Nigerian maize farmers been responding positively to real price incentive as a result of economic reform?
- If so, what is the magnitude of supply responsiveness in the short- and long-run? and
- What is the speed with which Nigeria maize farmers respond to changes in real price incentive?

- Is the response of maize farmers to real prices higher than their response to nominal prices?

It is generally believed that the responsiveness of farmers to price and non-price incentives (or disincentives) provides an indication of the contribution of the agricultural sector to the economy (Mushtaq and Dawson, 2003). For instance, Valdes (1989) argues that the larger the share of agriculture in GDP, the less elastic the supply of factors to agriculture and therefore the lower the aggregate supply response. In contrast, the smaller the share of agriculture in GDP, the higher the aggregate supply response given that the supply of factors to the sector will be more elastic. Importantly, the measurement of supply responsiveness of farmers is a veritable means of assessing the impact of economic reform or policy in the economy in view of the fact that the policies which provide the appropriate incentives (e.g., price incentives and efficient marketing system) would bring about high supply responsiveness while those that act as disincentives are less likely to do so.

It is on the strength of these issues that the current study aims at estimating the supply response of maize farmers in Nigeria to real prices from 1970 to 1998 using cointegration and error correction model.

MATERIALS AND METHODS

Analytical framework: Most supply response studies in Nigeria in the past have been based on the Nerlove (1958) model of adaptive price expectations and partial output (area) adjustment (Oni, 1969; Olayide, 1972; Garba *et al.*, 1998). However, this model has been widely criticised because of its *ad hoc* assumptions and a possibility of giving rise to spurious regressions as a result of the use of non-stationary time series (Mckay *et al.*, 1998). Consequently, the present study uses the method of cointegration and its implied error correction model to overcome the problems usually encountered with the use of the traditional Nerlovian model. In specific terms, the Johansen's method of cointegration, which results in the Vector Error Correction Model (VECM), was used. The vector error correction model is an extension of the Vector Auto-Regression (VAR) model developed by Sims (1980), Johansen and Juselius (1990), Johansen (1991).

Model specification: We specify a model relating Maize Output (LnMO) to Real Maize Price (LnRMP), Real Rice Price (LnRRP) as well as rainfall (LnWE), used as proxy for weather. The inclusion of the real rice price in the model

is to capture inter crop competitiveness in their cultivation. An increase in the real price of rice would, *ceteris paribus*, provide incentive for farmers to expand rice cultivation instead of maize and *vice versa*. Thus, real rice price would be expected to exhibit an inverse relationship with maize supply.

In this model, it is hypothesized that maize output, real maize price and real rice price are jointly determined (that is endogenous to the system) while the weather variable (as expected) is exogenous to the system. Consequent upon this condition, we straightforwardly specify the following Vector Error Correction Model (VECM):

$$\Delta Z_t = \delta + \Gamma_1 \Delta Z_{t-1} + \Gamma_2 \Delta Z_{t-2} + ... + \qquad (1)$$
$$\Gamma_{P-1} \Delta Z_{t-P+1} + \Pi Z_{t-P} + \psi X_t + U_t$$

Where:

Z_t is a (n×1) vector of jointly determined non-stationary I(1) endogenous variables; such that $\Delta Z_t = Z_t - Z_{t-1}$

X_t is a (q×1) vector of stationary I(0) exogenous variables

δ is a (n×1) vector of parameters (intercepts)

Π and Γ_i are (n×n) matrices of parameters

Ψ is a (n×q) matrix of parameters

U_t is a (n×1) vector of random variables, distributed as empirical white noise

Γ_I is a (n×1) vector of coefficients of lagged Z_t variables

Π is a (n×1) long-run impact matrix. The Π matrix is a product of two n×1 matrices α and β such that $\Pi_z = \alpha_z \beta$.

α_z represents the speed of adjustment coefficient

β represents the unique nature of the cointegration space

From Eq. 1

$Z_t = [LnMO_t, LnRMP_t, LnRRP_t]'$ and

$X_t = [LnWE_t]'$, where all the variables are as previously defined.

In the above specification, the information about the short-run and long-run adjustments to the changes in Z_t can be obtained through the estimates of Γ_i and Π, respectively. The Π matrix in Eq. 1, which is termed the long-run impact matrix of the error correction mechanism, is of primary importance. First the rank of Π provides the basis for determining the existence of cointegration or long-run relationship between

variables. According to Johansen (1988) there are three possibilities with regard to the rank of Π:

If rank (Π) is zero, then the variables are not cointegrated and the model is equivalent to a VAR model in first differences; if 0<rank (Π)<n, then the variables are cointegrated and if the rank (Π) = n, then the variables are stationary and the model is equivalent to a VAR model in levels.

Second, since the term ΠZ_{t-k} provides information about the long-run equilibrium relationship (cointegrating relationship) between the variables in Z_t, the Π matrix can be decomposed into the product of matrices α and β, that is, $\Pi = \alpha\beta$. Where α is the matrix of speed of adjustment coefficients which characterises the long-run dynamics of the system, while β is the matrix representing the cointegrating relations in which βZ_t (the disequilibrium error) is stationary (Johansen and Juselius, 1990; Chang and Griffith, 1998). A large value of α means that the system will respond to a deviation from long-run equilibrium very quickly (that is, with a rapid adjustment) and *vice versa*.

Given the above vector error correction model in Eq. 1, the long-run cointegrating equation for maize output can be written as:

$$LnMO_t = \phi_0 + \phi_1 LnRMP_t + \phi_2 LnRRP_t + \varepsilon_t \qquad (2)$$

Where:

ϕ_0 is a constant intercept term;

ϕ_1 and ϕ_2 are the long-run static coefficients; and

ε_t is the random term with the usual stochastic assumptions.

Model implementation techniques: The study adopts the Johansen Maximum Likelihood procedure of cointegration. In this method, a preliminary analysis is carried out first to assess the order of integration of the data series through the use of unit root tests after which we test for the existence of cointegrating (long-run *equilibrium*) relationships among the data series. If a valid cointegrating relationship is found, then we estimate a vector error correction model, since cointegration is a pre-condition for the estimation of an error correction model.

Test for unit roots: To carry out the unit root test for stationarity, the study uses the Augmented Dickey-Fuller (ADF) test to examine each of the variables for the presence of a unit root (an indication of non-stationarity), since it can handle both first order as well as higher order auto-regressive processes, by including the first difference in lags in the test in such a way that the error term is distributed as white noise. The test formula for the ADF is shown in Eq. 3.

$$\Delta Y_t = \alpha + \rho Y_{t-1} + \sum_{t-1}^{j} \gamma \Delta Y_{t-j} + \mu_t \tag{3}$$

Where: Y is the series to be tested; ρ is the test coefficient; and j is the lag length chosen for ADF such that μ_t is empirical white noise. Here the significance of ρ is tested against the null that, based on t-statistics on obtained from the OLS estimates of Eq. 3. Thus if the null hypothesis of non-stationarity cannot be rejected, the variables are differenced until they become stationary, that is until the existence of a unit root is rejected, before proceeding to test for co-integration.

Test for cointegration: The purpose of the cointegration test is to determine whether a group of non-stationary series are cointegrated or not. Engle and Granger (1987) pointed out that a linear combination of two or more non-stationary series may be stationary. Thus, if such a stationary linear combination exists, the non-stationary time series are said to be cointegrated. The stationary linear combination is called the cointegrating equation and may be interpreted as a long-run equilibrium relationship among variables.

To test for cointegration, we consider the vector error correction model specification in Eq. 1. Information about the number of cointegrating relationships among the variables in Z_t is given by the rank of the Π-matrix: if Π is of reduced rank, the model is subject to a unit root; and if $0<r<n$, where r is the rank of Π, Π can be decomposed into two (n x r) matrices α and β, such that $\Pi = \beta' Z_t$, where $\beta' Z_t$ is stationary. Here, α is the error correction term and measures the speed of adjustment in Δz_t and β contains r distinct cointegrating vectors, that is cointegrating relationships between non-stationary variables, as earlier stated.

The Johansen method uses the reduced rank regression procedure to estimate α and β and the trace

test and maximal-eigen value test statistics were used to test the null hypothesis of at most r cointegrating vectors against the alternative that it is greater than r. The interest here is in testing for the presence of a valid cointegrating vector which gives a unique long-run equilibrium relationship. Once this is established, the vector error correction model of the form given below can be estimated.

$$\Delta LnMO_t = \delta_{10} + \sum_{i=1}^{n} \delta_{1i} \Delta LnMO_{t-i} +$$
$$\sum_{i=1}^{n} \delta_{12i} \Delta LnRMP_{t-i} + \sum_{i=1}^{n} \delta_{13i} \Delta LnRRP_{t-i} - \alpha_1 \tag{4}$$
$$(LnMO - LnRMP - LnRRP)_{t-1} + LnWE + U_{1t}$$

$$\Delta LnRMP_t = \delta_{20} + \sum_{i=1}^{n} \delta_{21i} \Delta LnMO_{t-i} +$$
$$\sum_{i=1}^{n} \delta_{22i} \Delta LnRMP_{t-i} + \sum_{i=1}^{n} \delta_{23i} \Delta LnRRP_{t-i} - \alpha_2 \tag{5}$$
$$(LnMO - LnRMP - LnRRP)_{t-1} + LnWE + U_{2t}$$

$$\Delta LnRRP_t = \delta_{30} + \sum_{i=1}^{n} \delta_{31i} \Delta LnMO_{t-i} +$$
$$\sum_{i=1}^{n} \delta_{32i} \Delta LnRMP_{t-i} + \sum_{i=1}^{n} \delta_{33i} \Delta LnRRP_{t-i} - \alpha_3 \tag{6}$$
$$(LnMO - LnRMP - LnRRP)_{t-1} + LnWE + U_{3t}$$

Where all the variables are as earlier defined and Δ is the first difference operator, while δ_{11} to δ_{22} are short-run coefficients and α_1 to α_3 are error correction mechanisms that measure the speed of adjustment from short-run disequilibria to long-run steady-state equilibrium. U_{1t} to U_{3t} are error terms assumed to be distributed as white noise. Real prices were obtained by deflating the nominal prices with the Consumer

Table 1: Results of Augmented Dickey Fuller (ADF) unit root tests

Variable level	ADF statistic	Critical value	Variable First difference	ADF statistic	Critical value
LnMO	-0.8480	-3.6891	ΔLnMO	-6.7151	-3.6998
LnRMP	-2.4484	-3.6891	ΔLnRMP	-6.3601	-3.6998
LnRRP	-2.8313	-3.6891	ΔLnRRP	-7.2461	-3.6998
LnWE	-2.8626	-3.6891	ΔLnWE	-5.9079	-3.6998

Critical values of ADF tests are based on MacKinnon (1996) one-sided p-values. Lag length selection was automatic based on Eviews' Schwarz Information Criteria

Table 2: Results of multivariate cointegration tests

Null hypothesis	Eigen values	Trace statistic	Critical value 5%	Prob.	Max-Eigen statistic	Critical value 5%	Prob.
r = 0*	0.7300	40.0399	29.7979	0.0024	31.4325	21.1316	0.0013
r = 1	0.2333	8.6074	15.4947	0.4029	6.3769	14.2646	0.5653
r = 2	0.0887	2.2305	3.8414	0.1353	2.2305	3.8414	0.1353

Denotes rejection of the null hypothesis at the 5% level

Price Index (CPI). All the estimations were performed using the Standard Version of Eviews Econometric Software.

RESULTS AND DISCUSSION

Table 1 shows the summary results of unit root test of individual series used in the estimations. Clearly, it can be observed that on application of the ADF test on the log-level series, all of them were not stationary (that is contained a unit root) as indicated by the fact that their respective critical values are larger (in absolute terms) than the calculated ADF statistics, thus the null hypothesis of the presence of a unit root could be rejected, as they are all integrated of order one, that is I(1). Consequently we applied the ADF test on the log of the differenced series, to make them stationary. The calculated ADF test statistics in this case are higher in absolute terms than the critical values, thus we reject the null hypothesis of the presence of unit root and proceed to test for cointegration. Since the time series are non-stationary, it becomes necessary to test for cointegration. By using the log-level form of the series, we estimate a multivariate cointegration relationship to establish the existence of a long-run equilibrium relationship.

Cointegration tests: Table 2 shows the summary results of the Johansen's Maximum Likelihood cointegration test. The test relations were estimated with intercept and linear deterministic trend in a Vector Auto Regression (VAR) model of order 3 with a lag length of 3, which was found to be the most parsimonious for the data series. The Johansen cointegration tests are based on the Maximum Eigenvalue of the stochastic matrix as well as the Likelihood Ratio test which is in turn based on the Trace of the stochastic matrix.

From our results, it is evident that both the trace test and maximum eigenvalue test indicate one cointegrating equation as the null hypothesis of r = 0 is rejected. Thus, we conclude that there is a unique long-run equilibrium relationship between maize supply and real maize and real rice prices.

The Johansen model is a form of VECM and where only one cointegrating vector exists, its parameters can be interpreted as estimates of the long-run cointegrating relationship between the variables concerned (Hallam and Zanoli, 1993). Our cointegration coefficients normalised on maize supply are presented as long-run estimates in Table 3 in the section that follows.

Vector error correction estimates: Table 3 shows the results of the VECM estimates for supply response of

Table 3: Short- and long-run VECM estimates

Regressor	Long-run estimates		
LnMO(1)	1.0000		
LnRMP(1)	1.5038***		
	(3.2057)		
LnRRP(1)	-2.5798***		
	(-4.4598)		
Constant	-0.0991		
	Short-run estimates		
Error correction	ΔLnMO	ΔLnRMP	ΔRLnRRP
Coint Eq. 1 (ECM(-1))	-2.4009***	-0.2275	0.2796
	(-4.6285)	(-0.6640)	(0.9495)
ΔLnMO(-1)	0.7382	0.2789	-0.0874
	(1.7739)	(1.0146)	(-0.3703)
ΔLnMO(-2)	0.08169	0.1784	-0.0967
	(0.2897)	(0.9582)	(-0.6047)
ΔLnMO(-3)	0.0909	0.1683	0.0192
	(0.4687)	(1.3134)	(0.1748)
ΔLnRMP(-1)	2.5259***	-0.4216	-0.4015
	(3.2833)	(-0.8298)	(-0.9196)
ΔLnRMP(-2)	1.8394	-0.3353	-0.3210
	(2.8219)	(-0.7789)	(-0.8677)
ΔLnRMP(-3)	1.0172	-0.2134	-0.2404
	(2.3909)	(-0.7596)	(-0.9955)
ΔLnRRP(-1)	-4.6414***	-0.4758	-0.2321
	(-4.2045)	(-0.6526)	(-0.3704)
ΔLnRRP(-2)	-3.4444	-0.8013	-0.2345
	(-3.6522)	(-1.2864)	(-0.4381)
ΔLnRRP(-3)	-2.1195	-0.0269	-0.1784
	(-3.3122)	(-0.0637)	(0.4913)
Constant	-0.01094	0.0097	-0.0040
	(-0.1391)	(0.1880)	(-0.0896)
LnWE	0.3948	0.4317	0.3414
	(0.6431)	(1.0648)	(0.9798)
DiagnosticsR²	0.8606	0.7398	0.7526
Adjusted R²	0.7329	0.5013	0.5259
S.E. equation	0.3802	0.2511	0.2158
F-statistic	6.7385	3.1024	3.3195
Log likelihood	-2.5301	7.4237	11.0604
Akaike AIC	1.2108	0.3813	0.0782
Schwarz SC	1.7998	0.9703	0.6673

maize to changes in real prices. Both the short and long run estimates as well as diagnostics are presented. From the results, it can be observed that the model fits the observed data fairly well as indicated by the adjusted R² (0.7329) and F-statistic (6.7385) of the relevant error correction equation. Moreover, the signs of the coefficients meet *a priori* expectations. These together imply that maize supply response in Nigeria largely depended on real maize price, real rice price and weather during the period under study.

In the short-run, the relevant real maize price elasticity is 2.5259 and it is significant at the 1% level while in the long-run, the real maize price elasticity is 1.5038 which is equally significant at the 1% significance level. Clearly, both coefficients are elastic and suggest that 10% increase in real maize price increases maize supply by 25.259% in the short-run while the same percentage increase would raise the supply of maize by 15.038% in the long-run compared with 2.7588 and 1.9925 in the short and long-run in that order obtained in the past study.

By the same token, the rice price elasticity of maize supply is -4.6414 in the short-run, while the long-run estimate is -2.5798 both of which are elastic and significant at the 1% level. This implies that a 10% increase in the price of rice reduces maize supply by 46.414% in the short-run while the same amount of increase in rice price would reduce maize supply by 25.798% in the long-run compared with -2.6771 and -1.8033 in the short- and long-run respectively obtained from the previous study with nominal prices. This implies that in real terms increase in rice prices reduces maize supply by a larger amount than an increase in maize price would increase maize supply. Although the coefficient of the weather variable is not significant, it indicates a positive relationship with maize supply.

The error correction coefficient (-2.4009), which measures the speed of adjustment towards long-run equilibrium carries the expected negative sign and it is very significant at the 1% level. The coefficient indicates a feedback of about 240.09% of the previous year's disequilibrium from the long-run elasticity of maize and rice prices. This implies that the speed with which maize and rice prices adjust from short-run disequilibrium to changes in maize supply in order to attain long-run equilibrium is 240.09% within one year. This is very high and signals an overreaction of maize supply as a result of changes in real maize and rice prices. Furthermore, the speed of adjustment is higher than 207.82% obtained from the previous study with nominal prices.

CONCLUSION

One of the major points of departure in this study was to compare the response of maize farmers to real prices with their response to nominal prices from 1970 to 1998. Evidence has proven that maize farmers are equally responsive to real prices compared with nominal prices as in the previous study. The conclusions and policy implications of the previous study still make excellent sense in the current study in the face of the results obtained.

Results have shown that the response of maize supply to real maize price is very high, particularly in the short-run and with a higher adjustment toward long-run static equilibrium. The policy implication here is that since maize supply benefits by a larger than proportionate amount by increase in the real price of maize, their prices should be raised or at least not allowed to drop below their current levels by stimulating further demand. This can be achieved by increased industrial utilization for the production of other value-added commodities in addition to existing ones. Moreover,

increasing the current level of investment in the poultry sub-sector can raise the demand for feed from its current level, since it is evident that the poultry sub-sector is yet to be saturated judging from the continued rise in the prices of poultry meat and eggs, while reducing inflation rate will increase farmers' adjustment and hence increase their responsiveness.

Moreover, maize supply was found to be highly sensitive to changes in rice price both in the short- and long-run. This result implies that banning rice imports (to boost rice production, for example) could be very detrimental to maize supply because of the competitive nature of their production. Although not all rice that is domestically produced is grown on land that competes for maize production, most of it is grown under irrigated as well as rain fed conditions. In this regard swamp rice production should be highly encouraged. Besides, investment in high-yielding and early-maturing varieties of rice and maize can afford an opportunity of cultivating at least two crops of rice and one crop of maize (or *vice versa*) on the same land annually. This way, a balance could be achieved between maize supply and domestic rice production. In fact, the current diplomatic relationship that is being enjoyed between Nigeria and the republic of China can afford the country an opportunity of adopting the maize and rice hybrid technologies from the China Agricultural University, which has contributed in making the country a leading producer of cereals.

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