SUPPLY RESPONSE OF MAIZE, MILLET AND SORGHUM IN NIGERIA: AN ERROR CORRECTION MODEL APPROACH

Awotide, D. O.

Department of Agricultural Economics and Farm Management,
Olabisi Onabanjo University, Yewa Campus, Ayetoro, Ogun State, Nigeria
w_awotide@yahoo.com

Abstract

The paper quantified the yield responses of maize, millet and sorghum in Nigeria using error correction model. The analysis was carried out using a time series data covering 1966-2008. LR-test statistic showed that there was co-integrating vector implying a unique long-run equilibrium relationship with the assumption of linear deterministic trend in the data. The error correction model results indicated that maize, millet, and sorghum yield were not significantly dependent on the prices of maize, millet, and sorghum in the short-run with the exception of millet yield which was dependent on own price. In the long-run, maize yield was statistically dependent on the prices of millet and sorghum. The paper concluded that maize supply was influenced by market signals (prices) and hence small incremental changes in millet and sorghum prices have significant impact on national maize supply level. It is recommended that millet and sorghum price stabilization policy will go a long way in increasing maize production. This will have a consequential effect of increasing the welfare of maize farmers.

Key words: Maize, millet, sorghum, supply response, error correction model, Nigeria

Introduction

Nigerian domestic economy is dominated by agriculture, which accounts for about 40% of the Gross Domestic Product (GDP) and two-thirds of the labour force. Agriculture supplies food, raw materials and generates household income for the majority of the people. The food sub-sector of Nigerian agriculture parades a large array of staple crops, made possible by the diversity of agro-ecological production systems. The major food crops are: cereals - sorghum, maize, millet, rice, wheat; tubers-yam, cassava; legumes - groundnut, cowpeas; others– vegetables. These are the commodities that are of considerable importance for food security, expenditures and incomes of households. Of all the major food crops, cereals have risen to a position of preeminence. The importance of cereal grains as sources of food for man cannot be over emphasized, particularly in the developing nations. Grains, depending on the processing technique and the types of cereal employed, have offered a wide range of food products to man, particularly in the developing countries, but also to the animals in the developed countries. Millet, maize, rice and sorghum have formed the major food-based grains, particularly in Nigeria.

Price plays an important role in the selection of crops and generation of marketable surplus. Generally higher prices are expected to result in a larger output. Prices are therefore, among the most important determinants of the area under different crops. In economic analysis of the farm supply response, price is considered to be critical economic factor that determines farmers' production decisions (Ramulu, 1996). In addition, agricultural pricing policy plays a key role in increasing farm production and fundamental to an understanding of this price mechanism is supply response (Nerlove and Bachman, 1960).

Literature is replete on the supply response of crops (Adesina and Brorsen, 1987; Oni, 2000, Begum and Fakhrul, 2002; McDonald and Summer 2002, Tijani and Adejobi, 2009). While most of the studies concentrated on only one crop especially in Nigeria (Adesina and Brorsen, 1987-millet; Oni, 2000 – cotton; Tijani and Adejobi, 2009 - maize), this study estimated the supply response of maize, millet and sorghum in Nigeria to price changes. The hypothesis tested in the study was that positive relation exists between yield of maize, millet and sorghum and their prices. This means that increase in relative price of the crops in t-1 year leads to an increase in the yield of the crops in 't' years. In this study, cointegration analysis and Johansen's procedure were used to overcome the problem of spurious regression.

Methodology

Time Period and Data Requirement:

It is a time series analysis and covered the period 1966-2008. Annual data relate to yield (kg/ha), real wholesales prices (₦/ton), fertilizer consumption (tons), fertilizer subsidy (1 = if there is subsidy and 0 = otherwise), and irrigation. Real wholesale prices are nominal prices deflated by consumer price index (1985 = 100). Data on irrigation relate to areas equipped to provide water to the crops. These include areas equipped for full and partial control irrigation, spate irrigation areas, and equipped wetland or inland valley bottoms (Ramulu, 1996).

Analytical Techniques and Model Specification

Cointegration and Error Correction Models:

The traditional approach used for estimating aggregate supply response has been criticised on both empirical and theoretical grounds. The Nerlove and Griliches techniques seem unable to give an adequate clear-cut distinction between short-run and long-run elasticities, while the use of OLS may produce spurious results. Time-series analysis is the most widely used approach for estimating supply response. Modern time series techniques offer new promise. Cointegration analysis can be used with non-stationary data to avoid spurious regressions (Banerjee *et al*, 1993). When combined with error correction models, it offers a means of obtaining consistent yet distinct estimates of both long-run and short-run elasticities. Hallam and Zanouli (1992), Townsend and Thirtle (1994), Abdulai and Rieder (1995), and Townsend (1996), have used cointegration analysis and ECMs to estimate supply response at a commodity level, on the basis that they are preferable to the traditional partial adjustment model.

The first step in cointegration analysis is to test the order of integration of the variables. A series is said to be integrated if it accumulates some past effects, so that following any perturbance the series will rarely return to any particular 'mean' value, hence is non-stationary. The order of integration is given by the number of times a series needs to be differenced so as to make it stationary. If series are integrated of the same order, a linear relationship between these variables can be estimated, and cointegration can be tested by examining the order of integration of this linear relationship. Formally, variables are said to be co-integrated (*m*,*n*) if they are integrated of the same order, *n*, and if a linear combination exists between them with an order of integration, *m-n*, which is strictly lower than that of either of the variables.

In practice, economists look for the existence of *stationary* cointegrated relationships, since only these can be used to describe long-run stable equilibrium states. Indeed, if there is a linear combination between the variables which is stationary, I(O), then any deviation from the regressed relationship is temporary. Although the variables may drift apart in the short-run, an equilibrium or stationary relationship is guaranteed to hold between them in the long-run.

When variables are cointegrated (1,1), there is a general and systematic tendency for the series to return to their equilibrium value; short-run discrepancies may be constantly occurring but they cannot grow indefinitely. This means that the dynamics of adjustment is intrinsically embodied in the theory of cointegration, and in a more general way than encapsulated in the partial adjustment hypothesis. The Granger representation theorem states that if a set of variables are co-integrated (1,1), implying that the residual of the cointegrating regression is of order I(0), then there exists an error correction mechanism (ECM) describing that relationship. This theorem is a vital result as it implies that cointegration and ECM can be used as a unified empirical and theoretical framework for the analysis of both short- and long-run behaviour. The ECM specification is based on the idea that adjustments are made so as to get closer to the long-run equilibrium relationship. Hence, the link between cointegrated series and ECM is intuitive: error correction behaviour induces cointegrated stationary relationships and *vice-versa*.

The advantage of using ECM is twofold. First, spurious regression problems are bypassed. Second, ECM offer a means to incorporate the levels of the variables x and y alongside their differences. This means that ECM conveys information on both short-run and long-run dynamics. Nickell (1985) demonstrates that the ECM specification represents forward-looking behaviour, such that the solution of a dynamic optimisation problem can be represented by an ECM. The ECM can thus be interpreted as describing farmers reacting to ‘moving’ targets and optimising their objective function under dynamic conditions.

Agricultural supply response represents the agricultural output response to changes in agricultural prices or, more generally, to agricultural incentives (Mamingi, 1997). According to him, agricultural output or supply can be captured in any of the following (a) acreage or area under cultivation (b) yield or product per acreage unit and (c) product of acreage and yield. In this study, yield was used because it is reflection of output and acreage. The use of yield is replete in the literature (Rumulu, 1996; Mushtaq and Dawson, 2003).

Estimating equations and functional forms:
<u>Cointegrating equations:</u>
InMY = f(InMP, InMLP, InSP)
InMLY= f(InMP, InMLP, InSP)
InSY = f(InMP, InMLP, InSP)

Error correction model (ECM):

Maize ECM:

$$\Delta MY = \delta_0 + \sum_{i=1}^{3} \delta_{1i} \Delta MP_{t-i} + \sum_{i=1}^{3} \delta_{2i} \Delta MLP_{t-i} + \sum_{i=1}^{3} \delta_{3i} \Delta SP_{t-i} + \sum_{i=1}^{3} \delta_{4i} \Delta fertC_{t-i} + \delta_5\, fertsub + \delta_6 irrigation$$
$$- \alpha\left(MY_{t-1} - \beta_1 MP_{t-1} - \beta_2 MLP_{t-1} - \beta_3 SP_{t-1}\right) + \varepsilon_t$$

Millet ECM:

$$\Delta MLY = \delta_0 + \sum_{i=1}^{3} \delta_{1i} \Delta MP_{t-i} + \sum_{i=1}^{3} \delta_{2i} \Delta MLP_{t-i} + \sum_{i=1}^{3} \delta_{3i} \Delta SP_{t-i} + \sum_{i=1}^{3} \delta_{4i} \Delta fertC_{t-i} + \delta_5\, fertsub + \delta_6 irrigation$$
$$- \alpha\left(MLY_{t-1} - \beta_1 MP_{t-1} - \beta_2 MLP_{t-1} - \beta_3 SP_{t-1}\right) + \varepsilon_t$$

Sorghum model

$$\Delta SY = \delta_0 + \sum_{i=1}^{3} \delta_{1i} \Delta MP_{t-i} + \sum_{i=1}^{3} \delta_{2i} \Delta MLP_{t-i} + \sum_{i=1}^{3} \delta_{3i} \Delta SP_{t-i} + \sum_{i=1}^{3} \delta_{4i} \Delta fertC_{t-i} + \delta_5\, fertsub + \delta_6 irrigation$$
$$- \alpha\left(SY_{t-1} - \beta_1 MP_{t-1} - \beta_2 MLP_{t-1} - \beta_3 SP_{t-1}\right) + \varepsilon_t$$

Where:

MY = Maize yield (t/ha)
MLY = Millet yield (t/ha)
SY = sorghum yield (t/ha)
MP = Real price of maize (₦/t)
MLP = Real price millet (₦/t)
SP = Real price of sorghum (₦/t)
Δ = first difference
FertC = Fertilizer consumption (tons)
Fertsub = Fertilizer subsidy (1 = subsidy, 0 = otherwise)
Irrigation = Areas equipped to provide water as a proxy for technology
δ, α = parameters to be estimated

Results and Discussion

Unit root test:

Table I reports the results of testing the series (in logarithms) for unit roots using ADF – tests both with and without a linear trend. Since the computed t-values, which in absolute terms are smaller than the 1% critical values, we do not reject the null hypothesis that δ = 0, that is, the yields and prices exhibit unit roots. This implies that the series are non-stationary.

The first difference yields and prices series revealed that in absolute terms, the computed t-values exceed the 1% critical values. This implies that we can now reject the hypothesis that δ = 0. That is, the first-differenced yields and prices series do not exhibit unit root, which is to say that the series are stationary. This implies that they are 1(0) but the original yields and prices are 1(1) times series. ADF-tests also show that fertilizer consumption and irrigation series are 1(0).

Test for Cointegration

Since the yields and prices series were nonstationary, we are interested in determining whether the series are cointegrated with a view of identifying the cointegrating (long-run equilibrium) relationships. VAR-based cointegration tests were conducted using the methodology developed by Johansen, (1991 and 1995). Johansen's method is to test the restrictions imposed by cointegration on the unrestricted VAR involving the series. We used the LR-statistic to test the null hypothesis that the order of the VAR is K against the alternative that it is four where K = 0, 1, 2, 3. This also represent trace statistic. The results are presented in Table 2. The first row in the upper table tests the hypothesis of no cointegration, the second row tests the hypothesis of one cointegrating relation, the third row tests the hypothesis of two cointegrating relations, and so on, all against the alternative hypothesis of full rank, i.e. all series in the VAR are stationary. Based on the LR-test statistic, we conclude that there is cointegrating vector i.e a unique long-run equilibrium relationship with the assumption of linear deterministic trend in the data.

Table 3 shows the results of the cointegration rank test. The analysis provides the estimates of the cointegrating vector or relations. The cointegrating vector is not identified unless we impose some arbitrary normalization. The normalized cointegrating relation assuming one cointegrating relation r = 1 is given as provided in Table 3. The Johansen model is a form of error correction model (ECM) and, where only one cointegrating vector exists, its parameters can be integrated as estimates of the long-run cointegrating relationship between the variables concerned (Hallam and Zanoli, 1993).

The cointegrating vectors normalized on yield are:

Maize: $MY_t = -0.179MP_t + 3.436MLP_t + 3.166SP_t - 9.519$

Millet: $MLY_t = -5.994MP_t + 14.174MLP_t + 7.791SP_t - 8.602$

Sorghum: $SY_t = 5.345MP_t + 14.260MLP_t + 8.413SP_t - 8.353$

The coefficients represent estimates of long-run elasticities of the yield of maize, millet and sorghum with respect to the prices considered. In the maize model for example, the analysis shows that long run maize supply response to millet price was 3.44. This was within the elastic range. Norlove (1958) stated that long run is the sufficient time when full adjustment is possible and full adjustment is possible when the supply is elastic. The result of the study is, therefore consistent with the Nerlove's theory. Elastic supply means maize has alternative crops.

Table 4 presents the error correction model estimates for maize millet, and sorghum yield. The results indicated that maize, millet, and sorghum yield were not significantly dependent on the prices of maize, millet, and sorghum in the short-run with the exception of millet yield was dependent on own price. A one per cent increase in the millet price decreases the millet yield by 0.454 per cent. Sorghum yield was dependent on fertilizer subsidy in the short run. In the long-run, maize yield was statistically dependent on the prices of millet and sorghum. A one per cent increase in millet price increases the maize yield by 3.435 per cent while a one per cent increase in sorghum price decreases the maize yield by 3.166 per cent.

The most striking revelation that can be gleaned from the error correction model results in Table 4 is that there was low and insignificant long-run and short-run supply response for maize, millet and sorghum in Nigeria. This implies that in the economic analysis of maize, millet and sorghum supply response, price was not a critical economic factor that determines farmers' production decisions in the time period considered.

In this error correction model, Δ in prices, captures the short-run disturbances in yield whereas the error correction term u_{i-1} captures the adjustment toward the long-run equilibrium. Since the coefficients of the error correction term is statistically significant, it shows the proportion of the disequilibrium in yield in the period is corrected in the next period. Therefore, the coefficients of 0.121, 0.088, and 0.134 indicate that the deviation of maize, millet, and sorghum yield from the long-run equilibrium level is corrected by 12, 8, and 13 per cent respectively in the current period.

Conclusion and Recommendation

The paper quantified the yield responses of maize, millet and sorghum in Nigeria using error correction model. The analysis was carried out using a time series data covering 1966-2008. The most striking revelation that can be gleaned from the error correction model results is that there is low and insignificant long-run and short-run supply response for maize, millet and sorghum in Nigeria. This implies that in the economic analysis of maize, millet and sorghum supply response, price is not a critical economic factor that determines farmers' production decisions. However, the results indicate that prices of millet and sorghum can be used to manipulate maize supply in Nigeria. Therefore, the study concluded that maize supply was influenced by market signals (prices) and hence small incremental changes in millet and sorghum prices have significant impact on national maize supply level. It is recommended that millet and sorghum price stabilization policy will go a long way in increasing maize production. This will have a consequential effect of increasing the welfare of maize farmers.

References

Abdulai, A. and P. Rieder (1995), 'The Impacts of Agricultural Price Policy on Cocoa Supply in Ghana: an Error Correction Estimation', *Journal of African Economies*, 4(3), 315-35.

Adesina, A.A. and B.W. Brorsen (1987). A Risk Responsive Hectarage Response Function for Millet in Niger. *Agricultural Economics* 1:229-239

Banerjee, A., J. Dolado, J. Glabraith and D. Hendry (1993), *Cointegration, Error Correction and the Econometric Analysis of Non-Stationary Data*, Oxford: Oxford University Press.

Begum, M.A.A and S.M. Fakhrul (2002). Supply Response of Wheat in Bangladesh: An Application of Partial Adjustment Model. *Pakistan Journal of Biological Sciences*, 5(2): 225-229.

Hallam, D. and R. Zanoli (1993), 'Error Correction Models and Agricultural Supply Response', *European Review of Agricultural Economics*, 2, 111-20.

Johansen, S. (1991) "Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models," Econometrica, 59, 1551–1580.

Johansen, S. (1995) *Likelihood-based Inference in Cointegrated Vector Autoregressive Models*. Oxford University Press.

McDonald, J.D. and D.A. Summer (2002). "The Influence of Commodity Programs on Hectarage Response to Market Price: With an Illustration Concerning Rice Policy in the United States". University of California Agricultural Issues Center, Department of Agricultural and Resource Economics, University of California, Davis and Gianimi Foundation.

Mushtaq K. and P.J. Dawson (2003). "Yield response in Pakistan agriculture: a cointegration approach". Proceedings of the 25th International Conference of Agricultural Economics (IAAE). 16-22 August 2003. Durban, South Africa.

Nickell, S. (1985), 'Error Correction, Partial Adjustment, and All That: An Expository Note', *Oxford Bulletin of Economics and Statistics*, 47(2), 119-129.

Nerlove, M. (1958). *The dynamics of supply: estimation of farmer's response to price. Baltimore:* John Hopkins University Press.

Nerlove, M., and Bachman, K.L., 1960. "The analysis of changes in agricultural supply: problems and approaches". *Journal of Farm Economics.* 42: 531-554.

Oni, T.O. (2000). "Response of Cotton Output Supply to Price and Non-price Incentives in Nigeria". *NISER Monograph Series* No. 13 pp 54.

Ramulu, M. (1996). "Supply response of sugarcane in Andhra Pradesh". *Finance India*. Vol. 10, No. 1, Pg 116-122.

Tijani, A.A. and A.O. Adejobi (2009). An Application of Partial Adjustment Model to Supply Response of Maize in Nigeria. *Journal of Agriculture and Rural Development*, 3: 30-46.

Townsend, R. (1996). "Price Liberalization, Technology and Food Self Sufficiency: An analysis of summer grains in South Africa". Mimeo.

Townsend, R. and C. Thirtle (1995), "Dynamic Acreage Response: an Error Correction Model for Maize and Tobacco in Zimbabwe". University of Reading, *Discussion Papers in Development Economics, Series G, 2(20).*

Table 1. Unit root (ADF -) test statistic (Ho: 1 unit root)

Variable (1966-2005)	**Levels**		**First difference**	
	Non-trended	**Trended**	**Non-trended**	**Trended**
MY	-3.38	-3.45	-6.12	-6.07
MLY	-2.17	-1.92	-5.68	-5.88
SY	-2.04	-2.41	-5.29	-5.27
MP	-0.52	-1.99	-6.67	-6.85
MLP	-0.64	-2.35	-6.07	-6.16
SP	-0.28	-2.20	-6.32	-6.37
FC	-1.97	-0.83	-4.14	-4.76
IRRI	0.50	-1.50	-3.63	-4.04
*Critical values	-3.61	-4.20	-3.62	-4.22

*Mackkinnon critical values for rejection of hypothesis of a unit root at 1%.

Table 2. Results of LR-test statistic

Tested hypothesis	**Maize model**		**Millet model**		**Sorghum model**		
	Eigen value	**LR-test statistic**	**Eigen value**	**LR-test statistic**	**Eigen value**	**LR-test statistic**	**Critical values 1%**
No cointegration relation	0.481	38.157	0.473	36.076	0.446	36.624	54.46
1 Cointegration relation	0.225	13.893	0.209	12.386	0.244	14.744	35.65
2 Cointegration relations	0.112	4.477	0.095	3.722	0.107	4.374	20.04
3 Cointegration relations	0.002	0.092	0.000	0.009	0.005	0.197	6.65

Source: Eviews analysis computer printout.

Table 3. Normalized cointegrating coefficients: 1 cointegrating equation (r = 1).

	Yield	**Maize price**	**Millet price**	**Sorghum price**	**Constant**	**Log likelihood**
Maize model	1.000	-0.179	3.435	-3.166	-9.519	82.66
		(-0.270)	(2.198)**	(-2.837)**		
Millet model	1.000	5.994	-14.174	7.791	-8.602	97.054
		(0.831)	(-0.728)	(0.593)		
Sorghum model	1.000	5.345	-14.260	8.413	-8.353	77.249
		(0.859)	(-0.688)	(0.587)		

Values in parenthesis are t-values, **significant at 5%

Table 4. The error correction model estimates for maize, millet and sorghum yield.

	Coefficient for maize		Coefficient for millet		Coefficient for sorghum	
Regressors	**Short-run**	**Long-run**	**Short-run**	**Long-run**	**Short-run**	**Long-run**
Constant	-0.449	-9.519	0.073	-8.602	2.303	-8.353
	(-0.261)		(0.051)		(1.243)	
Δ MP	0.412	-0.179	0.293	5.994	-0.291	5.345
	(0.908)	(-0.270)	(0.792)	(0.831)	(-0.601)	(0.859)
Δ MLP	-0.052	3.435	-0.454	-14.174	0.181	-14.260
	(-0.197)	(2.198)**	(-2.105)**	(-0.728)	(0.643)	(-0.688)
Δ SP	-0.226	-3.166	0.068	7.791	0.163	8.413
	(-0.718)	(-2.837)**	(0.277)	(0.593)	(0.497)	(0.587)
Fertilizer consumption	0.151		0.218		0.109	
	(0.318)		(1.346)		(0.554)	
Fertilizer subsidy	-0.076		-0.071		-0.156	
	(-1.053)		(-1.224)		(-2.135)**	
Irrigation	0.087		-0.014		-0.413	
	(0.275)		(-0.054)		(-1.216)	
EC_{t-1}	0.121		0.088		0.134	
	(3.167)***		(2.764)**		(3.239)***	
R^2	0.68		0.73		0.70	
Durbin-Watson	1.85		2.21		2.096	

Values in parenthesis are t-values. ***significant at 1%, **significant at 5%