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Revision of the Nerlovian partial adjustment framework and its application to sorghum production in Nigeria

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An attempt was made in this paper to show how varying coefficients of adjustment might be incorporated into the Nerlovian partial adjustment framework and the resulting model applied to sorghum production in Nigeria. The nonlinear forms of the model were estimated with quasi-Newton iteration technique while the linear forms were estimated with regress. The estimated coefficients conform to theoretical expectations and were appropriately signed but with few exceptions. In addition, varying elasticity of supply was also obtained. The distribution of the adjustment coefficient and the elasticity were significantly different from zero.

Key words: Nerlovian partial adjustment framework, quasi-Newton iteration technique, regress.

INTRODUCTION

The original Nerlovian partial adjustment framework (Nerlove, 1956), which assumed that the adjustment coefficient is invariant with trend, is a two-model equation given as:

$$A^*_t = \alpha_o + \alpha_1 P_{t-1}$$
$$A_t = A_{t-1} + (1-\lambda)(A^*_t - A_{t-1}),\ 0 \le \lambda < 1$$

However, since the constraints preventing farmers from achieving set acreage targets are not the same year by year, the assumption may not necessarily hold through all the estimation period and beyond. Although the theoretical insight has indicated the possibility of varying the coefficients, most especially with regards to Nerlovian adaptive expectation framework, (Phillip, 1988; Nowshirvani 1971), there is no evidence of any empirical investigation to this fact. Therefore, an attempt has been made in this paper to show empirically how the coefficient might be varied with trend and the resulting model applied to sorghum production in Nigeria covering the period 1961 to 1997. In addition, varying elasticity of supply was also derived from the revised model.

Sorghum was chosen because according to NRC (1996), it has greater untapped potentials than any other crop. It was even postulated that if the twentieth century was the century of wheat, rice and maize, then the twenty-first century could become the century of sorghum. According to Gibbon and Pain (1985), sorghum remains an important food crop in dry areas and on poor soils. They also highlighted that very little of the sorghum produced globally enters world trade except that exported by the US. This then means that all that is produced is utilized locally. This has also been confirmed by Nmadu (1992) in a survey of some villages in Lavun local government area of Niger State. The sorghum grain is one of the highest produced in Nigeria as shown in Table 1. It is the most important cereal, its production surpasses all other crops (Norman 1972, FOS 1972, Federal Ministry of Education, Science and Technology 1984). The average yield in Nigeria is 897 kg/ha (FAO, 1973 - 1997).

METHODOLOGY

The partial adjustment framework assumes that the farmer uses the available price information to decide on the size of his farm to devote to any particular crop under production. The acreage decision may be fully achieved or partially achieved (hence the hypothesis) because of the other intervening factors that affect the production process. These factors may be socio-economic and natural. The present study investigated the factors that contribute to Nigerian farmers' failure to achieve planned sorghum hectarage. The basic hypothesis is a revised Nerlovian partial adjustment hypothesis which is a three-model

Table 1. Estimated output of major agricultural produce in Nigeria in '000 mt.

Crop	1988	1989	1990	1991	1992
Millet	2,432	2,809	2,949	3,760	3,921
G/corn	3,116	3,577	3,845	6,517	6,808
G/nuts	693	776	893	2,329	2,647
Beans	968	1,109	1,503	2,203	2,343
Yam	7,513	8,415	8,709	16,432	17,047
Cotton	141	168	184	292	201
Maize	2,075	2,449	2,816	5,289	6,111
Cassava	12,225	13,937	14,710	20,299	23,599
Rice	624	704	743	1,514	1,712
Melon	87	100	108	466	547
Cocoyam	541	711	764	2,293	2,492

Source: Federal Office of Statistics, 1996.

equation given as:

$$A^*_t = \alpha_o + \alpha_1 P_{t-1} + \alpha_2 Y_t + \alpha_3 W_{t-1} + \alpha_4 O_t + U_t \quad (1)$$

$$A_t = A_{t-1} + (1-\lambda_t)(A^*_t - A_{t-1}) \quad (2)$$

$$\lambda_t = a + b_1 Y_t + b_2 W_{t-1} + b_3 O_t \quad (3)$$
$$0 \le \lambda_t < 1$$

Where, A^*_t = planned farm size of sorghum in hectares in year t; A_t = achieved farm size of sorghum in '000 hectares in year t; A_{t-1} = achieved farm size of sorghum in '000 hectares in year t-1; P_{t-1} = price of sorghum in year t-1 in Naira/tone; Y_t = yield of sorghum in year t in kg/ha; W_{t-1} = wage rate in Naira/man-day in year t-1; O_t = Date of onset of rain in year t counted in days from January 1; λ_t = partial adjustment coefficient in year t; α's, a and b's = structural parameters to be estimated; U_t = error term assumed to be well behaved.

In the above equations, the planned acreage in a given year is assumed to be a function of the price received in the previous year and other exogenous variables. However, since planned acreage is not observable, there is need to re-model it in observable parameters, hence the partial adjustment hypothesis presented in equation 2. The hypothesis indicates that the actual acreage in a given year is a function of the acreage in the previous year plus a weight of the divergence between the planned acreage and the achieved acreage in the previous year. The partial coefficient is assumed to take a value between zero and one. If it takes a value of one, the hypothesis breaks down because planned acreage is indeterminate. In addition, a value of zero would suggest that achieved acreage is equal to planned acreage year by year, all previous observations are irrelevant. In both cases, the farmers were not given the chance to correct their errors. Of course, this kind of situation is not expected to prevail empirically. In previous attempts to study partial adjustment process of farmers (Nerlove, 1956), the adjustment coefficient was assumed invariant with trend. However, the adjustment process in a dynamic environment might be influenced by other factors. Since farming is a dynamic enterprise and farmers are expected to have flexible plans such that when better information becomes available, they can easily be incorporated into the plan, it was propose that the coefficient varies with trend and some factors were responsible for the variation as presented in equation (3).

Equations 1, 2 and 3 are now reparameterised to make them amenable for direct estimation. To start with, equation 1 was substituted into equation 2 to obtain the following:

$$A_t = (1 - \lambda_t)\alpha_o + \lambda_t A_{t-1} + (1 - \lambda_t)(\alpha_1 P_{t-1} + \alpha_2 Y_t + \alpha_3 W_{t-1} + \alpha_4 O_t) + (1 - \lambda_t)U_t \quad (4)$$

If equation 3 is substituted into 4, the following model is obtained:

$$A_t = \pi_o + \pi_1 A_{t-1} + \pi_2 P_{t-1} + \pi_3 Y_t + \pi_4 W_{t-1} + \pi_5 O_t + \pi_6 Y_t A_{t-1} + \pi_7 W_{t-1} A_{t-1} + \pi_8 O_t A_{t-1}\ \pi_9 Y_t P_{t-1} + \pi_{10} Y_t Y_t + \pi_{11} Y_t W_{t-1} + \pi_{12} Y_t O_t + \pi_{13} W_{t-1} P_{t-1} + \pi_{14} W_{t-1} W_{t-1} + \pi_{15} W_{t-1} O_t + \pi_{16} O_t P_{t-1} + \pi_{17} O_t O_t + V_t \quad (5)$$

Where,
$\pi_o = \alpha_o(1 - a)$; $\pi_1 = a$; $\pi_2 = \alpha_1 - a\alpha_1$; $\pi_3 = \alpha_2 - \alpha_o b_1 - a\alpha_2$; $\pi_4 = \alpha_3 - \alpha_o b_2 - a\alpha_3$; $\pi_5 = \alpha_4 - \alpha_o b_4 - a\alpha_4$; $\pi_6 = b_1$; $\pi_7 = b_2$; $\pi_8 = b_3$; $\pi_9 = -b_1\alpha_1$; $\pi_{10} = -b_1\alpha_2$; $\pi_{11} = -b_1\alpha_3 - b_2\alpha_2$; $\pi_{12} = -b_1\alpha_4 - b_3\alpha_2$; $\pi_{13} = -b_2\alpha_1$; $\pi_{14} = -b_2\alpha_3$; $\pi_{15} = -b_2\alpha_4 - b_3\alpha_3$; $\pi_{16} = -b_3\alpha_1$ $\pi_{17} = -b_3\alpha_4$; $V_t = (1 - \lambda_t)U_t$.

An examination of the partial adjustment model equation shown above indicates similarity with the adaptive model equation obtained by Phillip (1988). The main difference between them is the property of the error term. The error terms of the partial adjustment posses better properties than that of adaptive hypothesis, being only heteroskedastic in structure. Although this has to be confirmed empirically and appropriate action taken.

Let us now examine the equilibrium conditions of the above structural model. Based on existing theory of supply response of primary producers (Lim, 1975), it is expected that in equation 1, $\alpha_1 > 0$, $\alpha_2 < 0$, $\alpha_3 < 0$ and $\alpha_4 > 0$. It is not immediately possible to deduce the signs on a, b_1, b_2 and b_3 in equation 3, but supply theory suggested $\pi_2 > 0$, $\pi_3 < 0$, $\pi_4 < 0$ and $\pi_5 > 0$ in equation 5. However, if it is reasonably assume that $\alpha_o > 0$ in equation 1, then it would be expected that the signs on π_2, π_3, π_4 and π_5 will hold if $0 < a < 1$, $b_1 < 0$, $b_2 < 0$ and $b_3 < 0$ in equation 3. But if those signs hold, it would be observed to conflict with the signs on π_6, π_7 and π_8. Therefore, it was not possible to anticipate any signs on b_1, b_2 and b_3 ex ante.

By examining equation 4, it might be shown that the short-run elasticity of sorghum supply was given as:

$$\eta_{s,t} = \frac{\partial A_t}{\partial P_{t-1}} \cdot \frac{P_{t-1}}{A_t} = \frac{(1-\lambda_t)\alpha_1 P_{t-1}}{A_t} \quad (6)$$

The long-run elasticity of supply is given as:

$$\eta_{l,t} = \frac{\alpha_1 P_{t-1}}{A_t} \quad (7)$$

Equation 7 shows that the long-run estimate of elasticity is equal irrespective of the hypothesis used to estimate it (Phillip, 1988).

Four variants of model (5) were estimated through regression analysis using the ordinary least square and Quasi-Newton nonlinear iteration techniques as the case may be. The first was when $\alpha_2 = \alpha_3 = \alpha_4 = 0$ while the second was when λ_t, partial adjustment coefficient, was assumed to be zero. The third variant was when the first two restrictions were imposed at the same time on the model. The fourth is the general case when $\alpha_2 \neq \alpha_3 \neq \alpha_4 \neq 0$ and $0 \leq \lambda_t < 1$. However, since the model contain lagged values of the dependent variables among the explanatory variables, the problem of serial correlation made the efficiency of the least+squares estimates of the nonlinear forms of the models doubtful (for example Pindyck and Rubinfeld, 1976). Also, the Durbin-Watson test for serial correlation was inappropriate (Fotopoulos, 1995). Therefore, the nonlinear forms of the models were estimated using nonlinear Quasi-Newton iteration method provided by STATISTICA (a software by StatSoft Inc., 2325 East 13th Street, Tulsa, OK. 74104 USA, 1995).

The linear forms were estimated using OLS by REGRESS (Nmadu and Okolobah, 1998). The partial adjustment coefficients were entered using three different forms that is linear, semi log and exponential. The forms are:

$Y = a + b_l X_l$	linear
$Y = a + b_l \ln X_l$	Semilog
$Y = e^{a + b_l X_l}$	Expo 1
$Y = a_1 + a_2 e^{(b_l X_l)}$	Expo 2

The data used for this analysis were collected from various secondary sources as follows. Hectarage, yield and production data were collected from FAO (1972-1997) because of continuity and availability. Onset data were collected from two weather stations that is, Samaru Weather Station (IAR) and National Cereals Research Institute's Weather Station at Badeggi. Price series were collected from FOS (1960-1975), CBN (1986-1997), World Bank (1994) and Federal Ministry of Agriculture and Natural Resources (1997). However, certain limitations, including changes in the political structure of Nigeria in 1967, 1976, 1991 and 1995; and the nature of available series made it impossible to sample price series; therefore, it was the national average series that was used.

RESULTS AND DISCUSSION

Estimates of the structural parameters of equation 5 are presented in Table 2. The results showed that the amount of variation of sorghum acreage explained by the various cases in the models ranged from 2 to 81%. The amount of variation accounted for improved tremendously as movement was made from case one to case four across the various transformations of the adjustment parameter

Generally, case four gave better estimates and also accounted for greater amount of variation in sorghum acreage. This underscores a general reduction in ignorance and thus uncertainty, as more factors were included in the model.

However, the choice of which of each model to use for further analyses was not a straightforward process. Each form has its own strength and weakness as further noted by Pindyck and Rubinfeld (1976). They further hinted that choosing the best fit of a multi-equation model is a function of many factors including: (1) How well the model simulated the historical past. (2) error level of simulation and forecast. (3) consistency of estimated coefficients with economic reality and expected signs and (4) statistical significance of the coefficients estimated.

The above factors were therefore used to assess the validity of the models in question in order to select the best fit in this present study. Hence the historical simulations of the model (case four only) were carried out as shown in Figure 1. In addition, the error level of each estimated model is shown in Table 3.

A careful examination of the above analysis showed that none of the transformations had all the desired properties but Expo 2 gave a very poor approximation. Therefore, all the transformations at case four (except Expo 2) were selected for further analyses based on their individual strength. The estimated varying coefficient of adjustments for each model is presented in Table 4.

The results indicated that supply has increasing function and some of the shifter variables acted directly to alter sorghum supply while others acted indirectly through the adjustment parameters. In addition, the result shows that against expectation, onset of rains had decreasing trend on sorghum supply. This is quite unexpected, since, if the farmer is rational, then it is reasonable to expect that once rains have set, it is possible to a very high degree, to predict what may happen to sorghum production for the season. Early start of rains should encourage sorghum production while late start should discourage it. That however has not been the case with Nigerian farmers but that has not nullified the sense of their rationality. It just means that rationality demands that being a staple food, which is consumed by the farm family almost on a daily basis, no matter the physical and economic environment, the farmer will rather have some instead of nothing. The fact that farmers were undaunted about the prospect of failure indicates that with a strong water resource policy that ensures availability of irrigated water at all times, self-sufficiency in food production could easily be achieved using sorghum as a spring board. This kind of policy will also facilitate the achievement of planned sorghum acreage, hence reducing the adjustment parameter to zero since the uncertainty situation would have been reduced to that of risk.

The varying coefficients were generally of low order although cases of underestimation (< 0) were observed with the linear and semi log transformations. The highest estimate was obtained with linear while the lowest was obtained with Expo 1 (which actually converged to case two) transformations, respectively. It was observed that the distributions were generally significantly different from zero at the 5% level. Behrman (1968) has shown that the time required for adjustment to within 95% of coefficients of this order is between 30 - 50 years. The period under study witnessed a lot of macro level policy changes. Between the late '60s and early '80s, agricultural marketing was under the marketing boards hence price was under control. In addition, input supply (most especially fertilizer) was also government controlled with

Table 2. Structural estimates of the partial adjustments' model.

	λ_t	α_o	α_1	α_2	α_3	α_4	a_1	a_2	b_1	b_2	b_3	R^2	R^2 Change
Case 1	Linear	1154.692	1.209089	-	-	-	1.424258	-	- 0.00036***	0.002462***	- 0.00253***	0.59221	n.a.
			(9.715155)	-	-	-		-	(1.85E-08)	(5.32E-06)	(2.64E-06)		
	Expo 1	5193.383	0.088986***	-	-	-	- 0.30503	-	-3***	- 45.906***	-3***	0.56419	n.a.
			(5.88E-10)	-	-	-		-	(9.47E-07)	(0.001382)	(0.000134)		
	Expo 2	5182.855	0.046497***	-	-	-	- 258340	- 258340	-3***	- 52.6539***	-3***	0.035275	n.a.
			(9.68E-14)	-	-	-		-	(2.42E-07)	(0.000555)	(3.45E-05)		
	Semilog	4631.699	0.087294	-	-	-	5.424117	-	-0.56201***	- 0.22085***	- 0.17109	0.69456	n.a.
			(9428.258)	-	-	-	-	-	(0.17645)	(0.008346)	(0.235546)		
Case 2		7268.165	0.089**	- 2.054***	1.848	- 4.717	-	-	-	-	-	0.535501	5.08E-01
			(0.055)	(0.378)	(11.941)	(4.81)	-	-	-	-	-		
Case 3		5492.15	- 0.273	-	-	-	-	-	-	-	-	2.75E-02	n.a
			(0.278)	-	-	-	-	-	-	-	-		
Case 4	Linear	7001.226	0.111298***	- 1.64215	- 5.24887	-4.57627	0.921867	-	- 0.00065***	0.004663***	- 0.00324***	0.80949	0.21728
			(0.02331)	(1.325734)	(939.0476)	(518.0165)		-	(4.43E-07)	(0.001054)	(8.7E-05)		
	Expo 1	7199.064	0.335004***	- 1.54567***	- 53.6636***	- 5.16112***	- 1.04399	-	-2***	- 2.53114***	-2***	0.7134	0.14921
			(2.86E-09)	(2.33E-07)	(0.000114)	(9.72E-05)		-	(4.47E-07)	(0.000367)	(8.32E-05)		
	Expo 2	7091.59	0.312817***	- 1.35474***	-55.0628***	- 3.58306***	2.673081	-0.06003	-5***	- 0.64057***	-5***	0.67541	0.640135
			(5.93E-10)	(4.42E-08)	(2.38E-05)	(1.94E-05)		-	(5.57E-07)	(0.00041)	(9.89E-05)		
	Semilog	7314.066	0.089124	-1.8399	- 0.08597	- 6.66379	4.461605	-	- 0.45733***	- 0.01694***	- 0.27737***	0.81323	0.11867
			(8734.891)	(458874.4)	(15852.63)	(486121.3)		-	(0.043386)	(0.002052)	(0.000642)		

Values in parenthesis are standard errors; ***significant at 1% level; **significant at 5%; - = not estimated; n.= not applicable.

many of them being heavily subsidized. However, the marketing boards were abolished in 1986 and subsidy on fertilizer was removed in 1996 (a process which has commenced since 1991), paving way for a free-market economy, where the forces of supply and demand decide prices. With these changes, one would have expected that the farmers would either contract or expand their production. But the evidence here suggests that the farmers were generally not responsive to the changes. This assertion tends to lend credence to the fact that sorghum production was undertaken for more than economic reasons. This also tends to further demonstrate that policy changes must attack both social and economic reasons when crops of this nature are involved.

The estimated price elasticities of supply are presented in Table 5. The results conform generally to expectation that long-run elasticity is larger than short-run. This is because no matter the changes that occur in prices and other factors, the farmer is unable to change his production plan in the short-run (that is the period of gestation of the crop or within a growing season). But on the long run, because of better or perhaps worse information, the farmer is able to alter his plan. The distributions of the various elasticities were

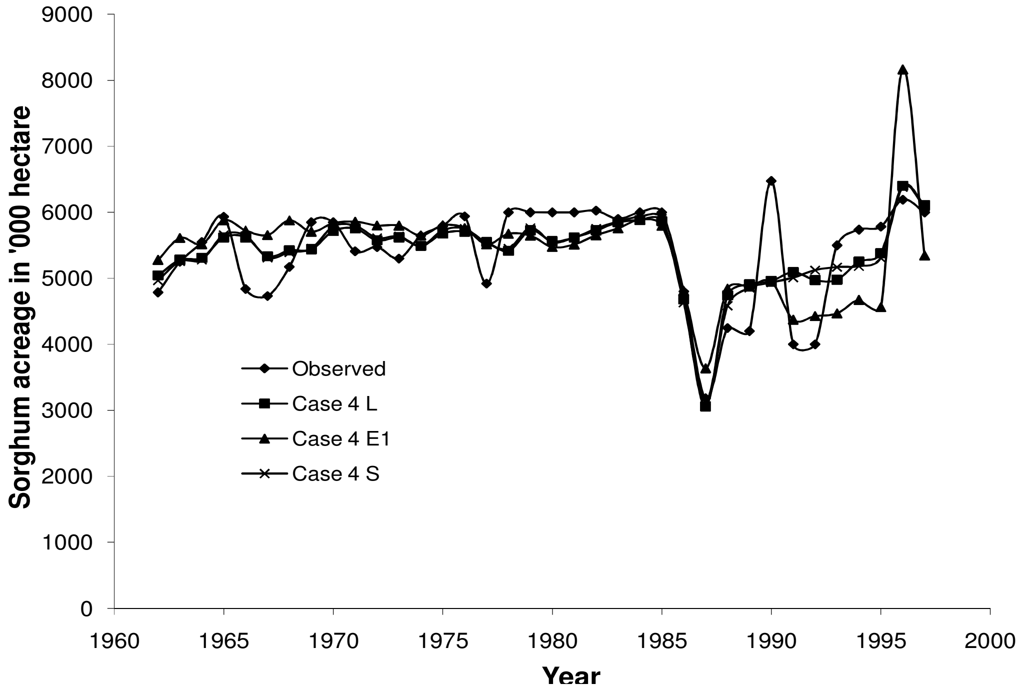

Figure 1. Historical simulation of partial adjustment models.

Table 3. Measures of validity of the estimated partial adjustments' models.

	λ_t	MARE	U	PTPE	RMSE	DW	ρ	Serial correlation
Case 1	Linear	0.093155	0.067021	0.351351	717.586284	2.5057	- 0.2408	No
	Expo 1	0.123748	0.070834	0.351351	756.7570624	1.1226	0.4376	Positive
	Expo 2	30884.91	0.999977	0.351351	192610036.6	1.2039	0.3991	Positive
	Semilog	0.093965	0.058634	0.351351	623.8846896	2.0828	- 0.4146	No
Case 2		0.073672	0.046515	0.486486	499.3207751	2.0172	- 0.00906	No
Case 3		0.120643	0.067465	0.486486	722.4971113	1.2353	0.3836	Positive
Case 4	linear	0.073678	0.045947	0.351351	493.056732	2.2232	- 0.1079	No
	Expo 1	0.092784	0.061175	0.351351	660.088617	2.0117	- 0.0118	No
	Expo 2	0.305165	0.187511	0.351351	2008.405375	2.3143	- 0.1662	No
	Semilog	0.070003	0.045477	0.351351	488.195086	2.1595	- 0.078	No

generally significantly different from zero at 5% level. However, unlike price elasticity of demand, the lower bound of price elasticity of supply is zero but that has not been the case here except with the Expo 1 transformation. The reason for this might be due to the subsistence nature of Nigerian farmers. They might have some cash obligations to settle (especially around the harvest time); as such they are forced to sell no matter the price. This means that at high prices, they sell less quantity while at lower prices they sell more quantity and as soon as the cash needed is obtained, they stop selling. This phenomenon has given rise to widespread hoarding of agricultural produce by the rich since supply at harvest always far outweigh demand, forcing the price downward. In this regard, the pricing policy needed is that which will prevent shortage (ceiling price) or surplus (floor price) in sorghum supply, rather than pursue a pricing policy that will ensure maximum return to the farmer.

Another important reason that may have contributed to this trend is lack of adequate storage facilities that make the farmer to dispose off whatever he cannot have space for. Therefore, sorghum supply is generally relatively

Table 4. Estimated varying coefficients of adjustment.

Year	Linear	Expo 1	Semilog
1962	0.031723	0	0.101978
1963	0.185254	0	0.237903
1964	0.125952	0	0.175578
1965	0.340009	0	0.457142
1966	0.220506	0	0.267939
1967	0.198536	0	0.239132
1968	0.291626	0	0.343752
1969	0.244602	0	0.282328
1970	0.333122	0	0.410931
1971	0.318112	0	0.356418
1972	0.314795	0	0.353796
1973	0.290123	0	0.321048
1974	0.226763	0	0.247458
1975	0.334657	0	0.363131
1976	0.3159	0	0.334788
1977	0.170387	0	0.194724
1978	0.291338	0	0.295763
1979	0.292521	0	0.292785
1980	0.181979	0	0.181218
1981	0.212711	0	0.207918
1982	0.285398	0	0.273315
1983	0.272941	0	0.350563
1984	0.389121	0	0.393994
1985	0.351528	0	0.334501
1986	-0.07058	0	-0.04413
1987	-0.48233	0	-0.22572
1988	0.119083	0	0.234913
1989	-0.02302	0	-0.03688
1990	0.012578	0	-0.01459
1991	0.100074	0	0.020231
1992	0.08879	0	-0.05452
1993	0.113937	0	-0.04384
1994	0.104553	0	-0.08305
1995	0.170455	0	-0.05361
1996	0.191749	0	-0.05567
1997	0.339081	0	-0.09728
Mean	0.196088	0	0.183061
St. Dev	0.162645	0	0.181687
Z test	7.233723	∞	6.045391

inelastic.

Conclusion

Empirical investigation into the possibility of incorporating varying coefficients of adjustment into the Nerlovian partial adjustment framework was shown in this paper. This helped in estimating varying elasticity of sorghum supply. The result has been very satisfactory and showed that adjustment towards the desired sorghum acreage is not invariant with trend. It therefore means that care must be taken to know the side the adjustment coefficient swings so that policy framework may not be faulted.

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