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Dynamic Acreage Response: An Error Correction Model for Maize and Tobacco in Zimbabwe

Abstract: The paper presents an empirical investigation of the supply of maize and tobacco for commercial agriculture in Zimbabwe. The error correction model, which employs the concept of cointegration to avoid spurious regressions, is used in the analysis. The factors affecting percentage area planted to maize were shown to be expected real maize price, real price of tobacco, real price of fertilizer and government intervention. The factors affecting percentage area planted to tobacco were shown to be real price of tobacco, expected real price of maize and institutional factors. The own price elasticity for maize was 1.44 and 1.76 in the short and the long run, respectively, for tobacco these were 0.28 and 1.36 in the short and long run respectively.

INTRODUCTION

The study of agricultural supply response has long been one of the most fruitful approaches to determining the effects of policy on agricultural output. Nerlove (1958) was largely responsible for formalising the dynamic approach, based on lagged adjustments and expectations. However, agricultural time series tend to be trended and regressions of trended data, even though giving high R^2s and significant *t*-values, may be spurious (Granger and Newbold, 1974). The recent literature on cointegration analysis addresses the problem of spurious regressions, when analysing non-stationary data. Under certain conditions, these series may be modelled using dynamic error correction models, which take account of the dynamics of short run adjustment towards long-run equilibrium in a theoretically consistent manner. This study applies these techniques to the supply of maize and tobacco, which are Zimbabwe's main food crop and export crop respectively. Cointegration is used to test long run equilibrium relationships between the time series and provides a framework for the analysis of supply within an error correction framework.

The next section outlines the concepts of cointegration and error correction. The data, the model and results are then described, with policy implications considered in the concluding section.

THEORY

Cointegration

The concept of cointegration states that if there exists a long run relationship between two variables, then the deviations from the long run equilibrium path should be bounded, and if this is the case, then the variables are said to be cointegrated. Two conditions must be satisfied for variables to be cointegrated. Firstly, the series for the individual variables

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must have the same statistical properties; that is, they must be integrated of the same order. If a series is stationary after differencing once, then it is said to be integrated of order one, or I(1). Stationarity tests are proposed by Fuller (1976) and Dickey and Fuller (1981), which determine if a series has a unit root (i.e., is non-stationary). These tests require the following regression

$$(1)\quad \Delta y_t = \alpha + \beta_t + (\rho - 1)y_{t-1} + \sum_{i=1}^{n} \lambda_i \Delta y_{t-i} + u_t$$

where Δy_t is the first difference in y_t, t is a trend term, n is the number of lags required to make the error term, u_t, white noise. The null hypothesis that the series has a unit root requires $(\rho-1) = 0$ or $\rho = 1$, indicating the process in nonstationary. In this case differencing y would yield a stationary process, that is: the process is difference stationary. The critical t-ratios are calculated by Fuller (1976). If the t-ratio for the coefficient $(\rho-1)$ is less than the critical value the hypothesis of a unit root is accepted and the series is non-stationary. If $(\rho - 1) < 0$ or $\rho < 1$ and the trend coefficient, β, is significant then y is trend stationary.

If the series are integrated of the same order, a static regression in the levels of the variables is run and tested to see if linear combinations of the variables are themselves integrated of the same order as the individual variables. If the variables are cointegrated, then there should exist a linear combination of these variables which is integrated of order one less than the individual variables. In the cointegrating regression

$$(2)\quad Y_t = a + bX_t + u_t$$

If Y~I(n) and X~I(n) then Y and X are said to be cointegrated if u_t~I($n-1$). In Equation (2), b measures the long run relationship between Y and X, and u is the divergence from the equilibrium path. If there is a stable long run relationship between Y and X, then the divergence from it should be bounded. Engle and Granger (1987) argue that if cointegration holds, then the error correction model is a valid representation of the adjustment process (the Engle and Granger two step procedure).

Testing the order of integration of the cointegrating regression error term can be performed using the Dickey-Fuller (DF) test, the augmented Dickey-Fuller (ADF) test, or the cointegrating regression Durbin-Watson (CRDW) proposed by Sargan and Bhargava (1983). These tests are the same as those used for determining the order of integration of the variables, but here it is the residuals that are being tested. OLS ensures that the cointegrating regression will give residuals having the smallest possible sample variance, so the critical values must be adjusted. Some of these adjusted vales are presented in Banerjee *et al.* (1993), MacKinnon (1991) gives the most comprehensive set of critical values using response surfaces.

Another disadvantage of the OLS approach is that in the multivariate case, there may be more than one cointegrating vector. Thus, in the OLS approach there is no guarantee that a unique cointegrating vector has been estimated. Thus, the DF, ADF and CRDW tests have been superseded[1] by the Johansen Maximum Likelihood estimation method (Johansen, 1988; Johansen and Juselius, 1990). This approach allows the estimation of all the cointegrating relationships and constructs a range of statistical tests.

The Error Correction Mechanism

If two cointegrated variables y and x are in stable equilibrium then

(3) $Y = bX$

but in the time series, $Y_t = bX_t$ may never be observed to hold. This discrepancy, $Y_t = bX_t$, contains useful information since on average the system will move towards equilibrium. If $Y_{t-1} - bX_{t-1}$ the previous disequilibrium, then the discrepancy should be useful as an explanatory variable for the next direction of movement of Y_t (Banerjee *et al.* 1993). Incorporating this observation into the variable changes model suggested by Granger and Newbold (1974) yields the error correction model. In effect, it reinstates the levels, and hence the long run considerations, into the differences specification which describes the short run relationships between variables.

The simplest error correction model involving X and Y takes the form

(4) $\Delta Y_t = \phi \Delta X_t - \alpha(Y_{t-1} - bX_{t-1}) + u_t$

where ϕ captures the short run effect on Y of the changes in X, and b accounts for the long-run equilibrium relationship between Y and X. u_t is the disturbance term, with zero mean, constant variance and zero covariance. $(Y_{t-1} - bX_{t-1})$ is the divergence from long-run equilibrium, so measures the extent of correction of such errors by adjustment in Y. The negative sign indicates that the adjustments are in the right direction to restore the long-run relationship (Hallam and Zanoli, 1993).

In the context of Hendry's 'general to specific modelling' the error correction model (ECM) can be derived as a simple reparameterization of a general autoregressive distributed lag model (Hendry *et al.* 1984). With regard to the relevance to agricultural supply analysis Salmon (1982) and Nickell (1985) show how the ECM can be derived from the dynamic optimizing behaviour of economic agents, within this framework Hallam and Zanoli (1993) show that the ECM avoids the partial adjustments unrealistic assumption of a fixed target supply based on stationary expectations.

DATA, BACKGROUND AND MODEL

The principle sources of the data used were the Zimbabwe Agricultural Marketing Authority, the Central Statistics Office, the FAO Fertilizer Yearbooks, the Zimbabwe Tobacco Association, and Thirtle *et al.* (1993), who derived a production data set from the CSO Production Accounts of Agriculture, Forestry and Fisheries, various University of Zimbabwe working papers, the Statistical Yearbook of Zimbabwe 1987, and various published and unpublished papers from the Ministry of Agriculture, Lands and Rural Resettlement. Annual data, for the commercial sector, from 1970–1989 were used in the analysis.

The main food and cash crops in the Zimbabwean agricultural sector are maize and tobacco respectively. Maize has been the staple diet of the rural population for many years. The marketing of maize, over the sample period, was carried out under strict government control through the Grain Marketing Board (GMB) and the producer price is set by

Government. This is normally announced after planting. Tobacco makes a substantial contribution to the foreign exchange earnings, having earned over 967 million Zimbabwe dollars in 1990, or some 26 percent of estimated foreign exchange earnings for the year. Tobacco cultivation, being labour intensive, also generates large-scale rural employment and accounts for 15 percent of the total population engaged in agriculture. The tobacco crop, however, is marketed by the Tobacco Marketing Board on a free-auction system with no government support given. 97 percent of all tobacco grown in the commercial sector is flue cured. As maize and tobacco are of such primary importance, in terms of food security and foreign exchange earnings, it is worthwhile understanding the relationships governing farmers' responses to price policy changes in these enterprizes.

The supply function for an agricultural output can be expressed as

$$(5)\quad Q_i = f(P_i, P_j, P_k, I, T)$$

where Q_i = quantity of output of good i supplied, P_i = price of output i, P_j = price vector of competing outputs, P_k = price vector of inputs, I = institutional constraints, infrastructure etc., and T = the state of technology. However, the dependent variable used is the area planted, rather than output, because this is under the control of the farmer to a much greater degree than output, which is subject to the effects of exogenous variables like the weather. Thus, acreage planted is a better indicator of planned production, as has frequently been noted in the literature (see Askari and Cummings, 1977).

Difficulties arise in accounting for on-farm use of maize, when calculating the maize area planted. However a fairly consistent series was derived which represented the area planted to maize that was to be sold to the Grain Marketing Board. For tobacco, the area planted figures were available, and unlike maize, all the tobacco is sold off the farm. Both series were divided by the total land area available to the commercial farmers, to allow for land purchased by government for resettlement purposes. The resulting series are the percentage areas of the commercial farms planted to maize and tobacco.

The expected price of maize was estimated in the manner suggested by Lawrance and Jayne (1992). This is necessary since even though there is a so-called preplanting announced price, in almost all of the past years the price has been announced after planting. The producers' expected price for maize is assumed to be a function of recent price trends and the level of stocks held by the GMB. The expected price is estimated as

$$(6)\quad P_t^* = a_0 + a_1 P_{t-1} + a_2 (Endstock)_{t-1}$$

where P_t^*= the expected real price of maize, P_t= real price of maize in year $t-1$, $(Endstock)_{t-1}$ = stocks of maize in tons at the end of year $t-1$, or beginning stocks in year t. The maize price was constructed as the average price of grade A, B, and C maize, which accounted for about 97 percent of all deliveries to the GMB from the commercial farmers. The expected price of tobacco was taken as the price received by farmers in the previous year.

In deciding how much of the crop to plant, farmers also take into account the opportunity cost of producing that crop, as Equation (5) shows. The competing crops in the supply of maize were taken to be soyabeans and tobacco. Maize was assumed to compete with tobacco, in the tobacco supply equations.

The key production costs for maize and tobacco are fertilizer and labour. There is a minimum wage rate set by government, and is known at the beginning of the season, the wage in year *t* was used. The fertilizer price is not lagged either, as most farmers purchase fertilizer at the beginning of the season and the price is known. The fertilizer price was quality–adjusted to allow for changes in the nutrient content. The hedonic regression technique used assumes that the price of a heterogeneous product is a function of its quality characteristics (see Cooper *et al.* (1993) and Rayner and Lingard (1971)).

Lastly, a dummy variable was included in the maize supply model to explain the collapse in commercial plantings in 1987/1988 (Beynon 1993), when there was a threat of price cuts if there was excess production. A dummy variable was included in the tobacco supply equation to capture the effects of sales quotas imposed on tobacco growers during the years 1967–73, 1976–77 and 1981–83. A simple time trend variable was included to represent technical change.

ESTIMATION AND RESULTS

Cointegration

Following section two, we begin by examining the statistical properties of the series. All the variables are generated by an AR(1) process except expected real maize price and the real soya price which are generated by an AR(3) and AR(2) process respectively. The DF/ADF tests showed that all the variables are integrated of order one, I(1), except for the real price of soya which appears to be I(0) (see Table 1). This satisfies the first condition for variables to be cointegrated, namely that they are integrated of the same order, I(1). The second condition is that there must be some linear combination of the variables which are integrated of order one less than the individual variables. The tests for cointegration are similar to those used to test for the order of integration, but they are based on the residuals, as was explained in section two. These tests have been superseded by the maximum likelihood methods proposed by Johansen, which provide likelihood ratio tests for the existence of different numbers of cointegrating vectors.

Maize area planted, expected real maize price, real tobacco price, real fertilizer price and government intervention yielded a maximum eigenvalue test and trace test that rejected the null hypothesis of no cointegrating vectors at the 95 percent level. The maximum eigenvalue test statistic is estimated as 44.6 against a critical value of 34.4 and a trace test statistic is estimated as 86.7 against a critical of 76.1. Both tests reject the hypothesis of more than one cointegrating vector with an eigen test statistic of 23.5 against a critical value of 28.1 and the trace test statistic of 42.0 against a critical value of 53.1. Thus there is only one cointegrating vector.

Tobacco area planted, real tobacco price, expected real maize price and quotas similarly yielded a maximum eigenvalue test and trace test that rejected the hypothesis of no cointegrating vector at the 95 percent level. The maximum eigenvalue test statistic was estimated as 41.9 against a critical value of 28.3 and a trace test statistic of 72.2 against a critical value of 53.1. Both tests reject the hypothesis of more than one cointegrating vector yielding an eigenvalue test statistic of 21.0 against a critical value of 22.0 and the trace test statistic of 30.3 against a critical value of 34.9.

Error Correction Model

Where only one such vector exists it can be interpreted as an estimate of the long-run cointegrating relationships between the variables concerned (Hallam and Zanoli, 1993). Thus, the estimated parameter values from these equations are the long run coefficients. The Johansen normalized estimates for maize are

$$(7)\quad Q_m = 1.76P_m - 0.88P_t - 0.69P_f - 1.13Dum + 7.23$$

and for tobacco they are

$$(8)\quad Q_t = 1.39P_t - 1.03P_m - 0.48Quota - 2.13$$

The error correction model for a single explanatory variable is shown by Equation (4) of section two. The ECM for maize (tobacco is entirely similar), with the variables listed, would be

$$(9)\quad \Delta Y_t = \Sigma\phi_{Yi}\Delta Y_{t-i} + \Sigma\phi_{Mm}\Delta P_{Mt-m} + \Sigma\phi_{Tn} + \Delta P_{Tt-n} + \Sigma\phi_{Fk}\Delta P_{Ft-k} + \phi_D\Delta DUM$$
$$+ \alpha(Y_{t-1} - b_M P_{Mt-1} - b_T P_{Tt-2} - b_F P_{Ft-1} - b_D DUM_{t-1})$$

The right hand side difference terms can be lagged a number of times, the length of lag being determined by the *t*-test. This model did not perform well with the limited number of observations available. However, as was explained in connection with Equation (4), ø captures the short run effect on Y of the changes in X, b accounts for the long-run equilibrium in the bivariate case. In order to reduce the number of variables to be estimated, thus increasing the degrees of freedom, the reduced form of the error correction model can be estimated. The residual term from Johansen cointegrating regressions in Equations (7) and (8) can be used to represent the bracket terms in Equation (9). The equation can thus be estimated as

$$(10)\quad \Delta Y_t = \Sigma\phi_{Yi}\Delta Y_{t-1} + \Sigma\phi_{Mm}\Delta P_{Mt-m} + \Sigma\phi_{Tn}\Delta P_{Tt-n} + \Sigma\phi_{Fk}\Delta P_{Ft-k} + \phi_D\Delta DUM + \alpha EC_{t-1}$$

This method only provides estimates for the short-run elasticities (the coefficients on the difference terms), but the parameters from the cointegrating regressions [Equations (7) and (8)] can be used as estimates of the long run elasticities.

The results reported in Table 2 are from models below chosen on the criteria of goodness of fit (variance dominance), data coherence, parameter parsimony and consistency with theory (Hendry and Richard, 1982).

The results in Table 2 show that percentage maize area planted is dependent on the real price of maize, the real price of tobacco, the real price of fertilizer and government intervention. The coefficient signs are consistent with *a priori* expectations. These results show that a 10 percent increase in the real price of maize will lead to an 14.4 percent increase in percentage area planted in the short run and a 17.6 percent increase in the long run. An increase in the expected real price of tobacco will cause a 8.8 percent decrease in maize area planted. A 10 percent increase in the real price of nutrient does not have a significant effect in the short run, but in the long run will decrease maize area grown by 6.8 percent.

Table 1 *Results of the DF/ADF Tests for Unit Root*

Variable levels	AR process	DF/ADF
Maize area	1	–2.6669
Tobacco area	1	–1.3921
Real fertilizer price	1	–1.9159
Real maize price	3	–2.7244
Real tobacco price	1	–2.7420
Real soya price		–3.8196
Real labour wage	1	–2.8658
Critical values		–3.0294
First differences		
Maize area		–4.4744
Tobacco area		–4.4857
Real fertilizer price		–4.4141
Real maize price		–7.4929
Real tobacco price		–6.4621
Real labour wage		–4.7642
Critical values		–3.0401

Notes: All the variables are in logarithms. The prices were deflated by the consumer price index.

Table 2 *Maize and Tobacco Supply: ECM Estimates*

Explanatory variables	Coefficients for Maize		Coefficients for Tobacco	
	Short-run	Long-run	Short-run	Long-run
Constant	-	7.23	-	–2.13
ΔP_{Mt}	1.44 (2.89)	1.76	-	–1.03
ΔP_{Tt-1}	–0.45 (–1.98)	–0.88	0.28 (3.93)	1.36
ΔP_{Ft}	-	–0.68	-	-
ΔDUM	–0.80 (–3.53)	–1.13	–0.17 (–5.10)	–0.48
EC_{t-1}	–0.79 (–2.64)		–0.34 (–5.83)	
R^2	0.76		0.79	
DW	1.8		2.2	

The result for tobacco show a similar degree of fit. Real tobacco price, real maize price and institutional factors, quotas, affected the percentage area allocated to tobacco. A 10 percent increase in the real price of tobacco will lead to a 2.8 percent increase in area planted in the short run and a 13.6 percent in the long run. The application of quotas will lead to a 1.7 percent decrease in area planted. Maize has a non significant effect in the short run but a 10 percent change in the real price will cause a reduction of 10.1 percent in area planted to tobacco in the long run.

The error correction coefficient (EC) measures the adjustments towards the long run relationship between maize area planted and maize price, tobacco price and fertilizer price, in the case of maize. In the case of tobacco, area planted, tobacco price, maize price and institutional constraints. The error correction term for maize is much larger (0.79) than for tobacco (0.34) indicating that the adjustment for maize area planted towards the long run relationship is almost completed in the current period while adjustment for tobacco is much slower. This is to be expected, as there is a larger infrastructure and human capital costs for tobacco cultivation, in terms of constructing curing barns and gaining managerial knowledge, whereas these requirements are less for maize.

All the tests for model adequacy yield satisfactory results when applied to the maize equation. The DW statistic indicates no residual serial correlation, further investigation using the Lagrange multiplier test for first and second order serial correlation yield an F-version of 0.0013 well below the critical values. The RESET test for functional form mis-specification yields a value of 0.88 which is below the critical value of 4.84, this indicated acceptance of the hypothesis of correct functional form. The Jarque–Bera test for normality in the residuals gives a value of 1.22 thus accepting the hypothesis of a normally distributed residuals. The heteroscedasticity test yields a value of 0.79 indicating no heteroscedasticity in the residuals.

The tobacco estimates also yield satisfactory results. The Lagrange multiplier test gave a value of 0.16, the Jarque–Bera test for normality yielded a value of 1.26, the test for heteroscedasticity yielded a value of 3.83 and the RESET test for correct functional form gave values of 1.41. All tests are accepted at the 95 percent level.

The error correction formulation of the model was tested against the more restrictive partial adjustment model, by imposing zero restrictions on the difference terms. The Wald test used yielded a x^2 of 46.04 for maize and 36.12 for tobacco. Both outcomes are above the critical values at the 95 percent level, so the additional restrictions imposed by the partial adjustment are rejected. Thus, the error correction model is preferred to the partial adjustment formulation.

CONCLUSION

These results show the commercial farmers to be highly responsive to output prices. The percentage area planted to maize depends on the expected real price of maize, the real price of tobacco, the real price of fertilizer and government actions. The percentage area of tobacco planted depends on the real tobacco price, the expected real maize price and institutional factors, such as quotas.

The government can have a strong influence on the cultivated area of maize, as the state controls the maize price. A 10 percent increase in the maize price will increase the cultivated area by 14 percent in the short run and over 17 percent in the long run. In the light of the recent debate on fertilizer price liberalization, the effect of fertilizer prices on food security is a major issue. These results show that a 10 percent increase in the fertilizer price will decrease maize cultivation by 6.8 percent in the long run, although the effect in the short run will not be significant. Although the commercial sector does not produce the majority of the maize its contribution is significant. The government also has the option of offsetting the decrease in maize area planted as a result of increased fertilizer prices, by increasing the maize price. However the opportunity costs of supporting commercial agriculture would need to be considered.

Input costs do not have a significant impact on the area planted to tobacco. This is probably due to the high returns to tobacco cultivation. The short run price response is small, due to the infrastructure costs described above, but in the long run farmers are extremely price responsive.

The insignificance of the wage rate variable also has implications. The minimum wage legislation may have decreased farm employment, but these results suggest that wages are not sufficiently high to influence production decisions.

The overall performance of the models suggest that these results provide useful information on the supply relationships. When considering policy analysis, however, additional limitations need to be considered. These include data limitations, partial analysis and long run macroeconomic effects such as the structural effects of the increased export earnings of tobacco on the rest of the economy. Zimbabwe has a dualistic agricultural sector, the large scale commercial sector and a small scale, basically subsistence sector therefore policy analysis should also consider distributional, equity and productivity effects.

NOTE

[1] They are discussed here because they are far more comprehensible than the Johansen approach that is actually used here.

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DISCUSSION OPENING — B.J. Revell *(Scottish Agricultural College and University of Aberdeen, UK)*

It is always heartening at an international conference to find a paper which is of more immediate relevance and application in the host country. The authors are thus to be congratulated for focusing their analysis of supply response on commercial production of maize and tobacco in Zimbabwe, which touches on fundamental issues underlying the wider questions of food security and foreign exchange earnings.

My comments on the paper cover three broad areas: methodology; model specification, estimation and interpretation and finally policy implications.

Methodology Co-integration analysis is something of the latest fashion in the analysis of economic time series, addressing specifically the problem of spurious regression relationships arising out of non-stationarity or trend in the variables. Traditionally, appropriate differencing of the data will ensure a stationary series. The difficulty arises in the estimation of equations specified purely in difference form (i.e. trend removed), since they only measure short-run responses. The error correction model (ECM) re-introduces variables in levels into the specification, thereby ensuring that there is a long-run equilibrium solution consistent with the hypothesized model.

In fact, the error correction model is only a special case of the ARMAX models, and ultimately, of the transfer function noise(TFN) models (Box and Jenkins 1976, Jenkins 1979) in which the generating process for the noise model is specified precisely, rather than modelled as an ARIMA process as in the TFN model. Indeed, since TFN models are capable of representing both partial adjustment processes and price expectations (adaptive and rational), then one wonders why they are not applied more in the context of supply response analysis. Certainly, the identification and estimation process is no more complex than that required to identify co-integrating vectors in the multivariate case, albeit that OLS can then be used for estimation of ECMs.

Furthermore, the impulse response function of the TFN will give both the short run and long-run responses(gain) of the system being modelled. Finally, the parameters of the noise model are estimated jointly with the 'structural' or economic parameters. In the ECM, the innovation series or deviations from equilibrium are generated through separate equation estimated in levels. The validity of the parameter on the error correction term thus depends upon having the right long run model.

Model Specification and Estimation The model specification is in terms of area shares, rather than area planted. Whilst this does enable the model to account for land redistribution from the commercial to the traditional sector, it does give rise to some confusion and errors in the exposition and interpretation of the results. The 'elasticity' estimates actually measure percentage changes in area shares resulting from percentage price changes, and not to changes in 'area planted' as the authors claim, nor even in the percentage points change in allocation of commercial land to maize and tobacco. It would have been helpful to have data on the maize and tobacco area shares to put in context the adjustments which might be implied both for these and other crops.

The authors do address price expectations formation, although the process for tobacco is given somewhat cursory treatment in view of the importance of tobacco to the economy. Since tobacco prices are determined outside an institutional framework, the nature of producer price expectations formation is likely to be more complex than that for maize, and surely deserves more consideration than a single period lag on the own price (change) variable. Is it not also likely that there is greater price uncertainty for tobacco than for maize, and this will also contribute towards the lower adjustment rate for this crop?

The ECM is a reversible supply function. I also wonder whether this is tenable in the case of tobacco, given the capital investment associated with its storage and processing.

Interpretation The authors draw some policy implications for the maize and tobacco sectors from their model. It is here that some reservations arise.

Whilst maize appears to respond to fertilizer prices, a 10 percent increase will decrease the area share by 6.8 percent in the long run, not the actual area planted as the authors state. Furthermore, since the traditional sector produces most maize, the question should perhaps more appropriately be examined through supply response analysis in this sector, and where the biggest impact of fertilizer price change will be on yields and production rather than area planted.

The interpretation of wage rate impact in the paper is also problematic. The authors conclude that wages 'are not sufficiently high to influence production decisions'. Given the scarcity of forex for capital investment in Zimbabwe over the period of estimation, might this not have inhibited the substitution of capital for labour, and thus made changes in production relatively invariant to wage rate changes?

Conclusions The authors have demonstrated an interesting application of the ECM and co-integration analysis in the context of supply response in the commercial sector of a developing country. The emphasis has been on modelling technique rather than on modelling to answer specific policy questions. The fundamental question is whether such sophisticated approaches are tenable in relation to the traditional agricultural sectors of sub-Saharan Africa.

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