Supply response of Zimbabwean agriculture: 1970–1999

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Abstract

This paper uses data that spans different pricing regimes to estimate the aggregate agricultural supply response to price and non-price factors in Zimbabwe. The autoregressive distributed lag (ARDL) approach to cointegration employed here gives consistent estimates of supply response in the presence of regressor endogeneity and also permits the estimation of distinct estimates of both long-run and short-run elasticities when exogenous variables are not integrated of the same order. The results confirm that agricultural prices in Zimbabwe are endogenous and the exogenous variables are not integrated of the same order hence use of the autoregressive distributed lag approach was worthwhile. The paper finds a long-run price elasticity of 0.18, confirming findings in the literature that aggregate agricultural supply response to price is inelastic. This result means that the agricultural price policy is a somewhat blunt instrument for effecting growth in aggregate agricultural supply. The provision of non-price incentives must play a key role in reviving the agricultural sector in Zimbabwe.

Keywords: Agricultural supply response; Autoregressive distributed lag; Cointegration

Cette article utilise des données qui englobent différents régimes de fixation des prix pour évaluer l'ensemble de la réponse de l'approvisionnement agricole en réaction aux facteurs de prix et de non-prix au Zimbabwe. L'approche autorégressive de décalage distribué (ARDL en anglais) de la cointégration, utilisée ici, fournit des évaluations cohérentes concernant la réponse en approvisionnement en la présence de variable indépendante endogène et permet également l'évaluation des estimations distinctes des élasticités à la fois sur le long et le court terme lorsque les variables exogènes ne sont pas intégrées dans le même ordre. Les résultats confirment que les prix agricoles au Zimbabwe sont endogènes et que les variables exogènes ne sont pas intégrées dans le même ordre, justifiant ainsi l'utilisation de l'approche autorégressive de décalage distribué. L'étude révèle une élasticité des prix de 0.18 sur le long terme, confirmant les conclusions émises dans la littérature que l'ensemble de la réponse en approvisionnement agricole en réaction aux prix est rigide. Ce résultat signifie que la politique des prix agricoles est en quelque sorte un instrument inefficace et peu enclin à provoquer une croissance de l'ensemble de l'approvisionnement agricole. La provision d'incitations au non-prix doit jouer un rôle clé dans la relance du secteur agricole au Zimbabwe.

Mots clés : *Réponse en approvisionnement agricole ; Décalage distribué autorégressif ; Cointégration*

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1. Introduction

This paper provides empirical evidence on the supply responsiveness of Zimbabwe's agricultural sector from the econometric estimation of supply elasticities with respect to price and non-price factors. Estimates of supply responsiveness are useful guides to economic policy formulation, especially in the light of the astonishing collapse of the Zimbabwean economy after the controversial land reform. While both price and non-price factors may be important, this paper emphasizes the role of pricing policy in enhancing agricultural activity. The focus is also on the aggregate sector rather than individual crops. (For an example of an individual crop study for Zimbabwe see Leaver, 2004.)

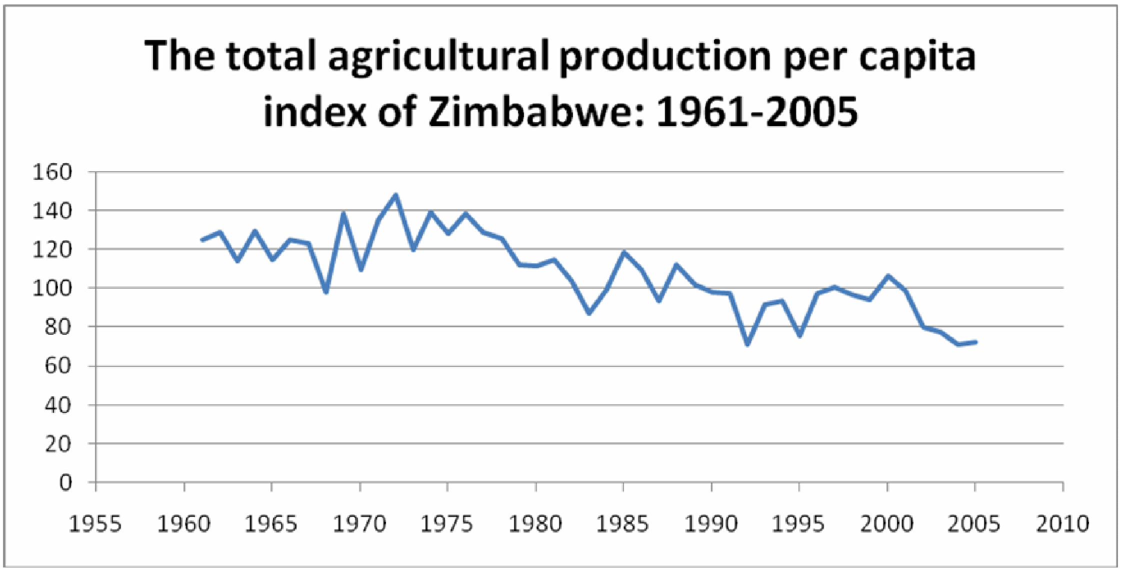
Before 1970, agricultural producer prices were largely set at levels aimed at protecting white farmers. During the 1970s, producer prices were set on a cost of production basis negotiated annually between the Commercial Farmers Union and the government, but consistent with subsidized prices to urban consumers in a bid to keep wages down and to buy political support for the government. After independence in 1980, the smallholder representatives were also included in the annual price negotiations. However, increasingly throughout the 1980s, producer prices were influenced by the state marketing board deficits, which were caused by the costs of establishing widespread commodity collection points, and by the low controlled selling price, which was designed to benefit consumers. Real prices for commodities declined during the 1980s. In the 1990s, state marketing boards were given greater autonomy in pricing and business decisions. The 2000s saw the reintroduction of price controls on major grains (Muir-Leresche & Muchopa, 2006).

Traditionally, agriculture has been the second largest contributor to GDP (Gross Domestic Product), the largest employer of labor, the largest contributor to export earnings, a significant source of raw materials for the manufacturing sector, and the supplier of the nation's food requirements. Clearly, the agricultural sector is still of great importance to Zimbabwe and knowledge of its supply responsiveness may help policy makers use the sector to spearhead external and internal adjustment processes. In fact, any hopes of reviving the economy will necessarily have to include strategies focused on the agricultural sector. If agriculture is highly responsive, then policy reform induced changes in relative prices could bring about increased exports to restore external balance. Also, agricultural response in the form of increased food production could help moderate inflation and thus contribute to the process of internal adjustment.

However, using agricultural policy instruments to affect agricultural activity without empirical knowledge of the structural parameters of supply means that the policy instruments may be used inappropriately and thus produce unintended results (Mumbengegwi, 1990). It is necessary to know the exact responses of agricultural supply if an effective overall agricultural policy is to be implemented. Thus this study is valuable because it could help policy makers identify the key variables that are important in determining agricultural supply. Policies would then be formulated on the basis of empirical evidence on the significant variables. Once the quantitative impacts of the policy variables are established they can be used to achieve the desired objectives.

2. Statement of the problem

In Zimbabwe several constraints have been identified as hindering agricultural growth. These include the land policy, the agricultural pricing policy, the trade and exchange rate policies and technology. During the time that these constraints have been observed, the agricultural sector has never been able to maintain its position as the major contributor to GDP. In 1999 the sector contributed 27.5% of GDP and this has been declining since 2000 (FAO, 2006), and various other agricultural performance indicators provide further evidence of the relative deterioration of the agricultural sector since then. For instance, the total agricultural production per capita has been declining, as shown in Figure 1.



Source: FAO, 2006

Note: 1999–2001=100

Figure 1: The total agricultural production per capita index of Zimbabwe : 1961–2005

The food production per capita index has also been falling, particularly since 2000. This partly explains the rampant food shortages that Zimbabwe has witnessed, with consequent increases in domestic food prices and the dramatic increases in agricultural imports than have been observed since 2000.

Controlling for the effects of the land policy, it seems that the pricing policy is one of the major factors at the heart of Zimbabwe's agricultural activity stagnation in terms of output. In fact, as Muir-Leresche and Muchopa (2006) document, real producer prices for commodities declined during the 1980s, which reduced farm profits and contributed to a reduction in the area planted for some crops. The liberalization of the market system in the 1990s generated some positive effects for many farmers. However, the return to maize and wheat marketing monopoly and price controls since 2000 has been a source of great concern to farmers (Muir-Leresche & Muchopa, 2006). Thus, all things being equal, it seems plausible that the failure to provide price incentives constrains agricultural growth. In the hyperinflationary Zimbabwe, the officially controlled consumer prices have kept farm producer prices very low relative to inflation.

The factors affecting the agricultural sector have thus also contributed to the poor performance of the national economy, as it has traditionally depended heavily on agricultural growth and export earnings. For the national economy to grow, the agricultural sector should provide a surplus over and above the needs of the agricultural population. So agricultural activity should be stimulated to increase farmers' purchasing power and hence improve the domestic market for non-agricultural products in the rural sector, to increase food supplies and agricultural raw materials, to facilitate transfers of labor and other resources from agriculture for industrial development, and to increase foreign exchange earnings from agricultural exports.

The contribution the agricultural sector can make in these areas will depend on the responsiveness of domestic agricultural production to economic incentives and to price signals in particular. Any meaningful attempt to reform the structure of incentives provided by the land policy, the agricultural pricing policy, the trade and exchange rate policies in favor of the agricultural sector, and hence the national economy, will require a detailed knowledge of the supply response parameters of the agricultural sector, inter alia. The provision of these supply response estimates in order to create a basis for further policy reforms is the main motive for this study.

3. Theoretical framework

The modeling of the aggregate supply response has its foundations in the theory of the firm. Since our interest is only in the output supply function, and not in input demand functions, we take the commonly used approach of expressing the firm's problem from an output perspective. Such an approach assumes that optimization has already been achieved in the input space and that the firm uses the least cost combinations for the production of any output level. This least cost approach is conceptually plausible because producers would want to produce a given output with the minimum cost outlay rather than try to directly optimize in the input space by equating marginal factor productivity to marginal factor cost. Producers are only aware of what they pay for inputs and do not generally have an idea of the input marginal productivities.

A profit maximizing firm produces output up to the point where it equates marginal revenue to its marginal cost. When producers are price takers, as is generally the case for farmers, profit maximization behavior equates the marginal cost to price. As such, the firm's supply function is simply its marginal cost function. The supply function is defined only in the range where price is greater than or equal to the minimum of the average variable cost. So the quantity of a product produced and supplied depends on its own price, the prices of substitute and complementary products, and the prices of inputs.

Supply can thus be expressed as the inverse of the marginal cost function and is increasing in the market price – the fundamental result from the theory of the firm is that price is the most important determinant of supply.

The analysis underlying the theory of the firm assumes instantaneous response between inputs and outputs, which is not applicable for agriculture. Firstly, the agricultural sector is characterized by biological lags between input application and output production. Secondly, for the agricultural firm the technical rules implied by the production function may actually change during the production process. Thirdly, for agricultural firms, there exist technological and institutional factors that prevent intended production decisions from being fully realized during any one period. Fourthly, the assumption of perfect knowledge and foresight is not valid for the majority of agricultural firms – the agricultural sector is characterized by high imperfections in price and other information. Finally, the risk and uncertainty faced by agricultural firms is much higher than that faced by other standard firms – as a result the production behavior of agricultural firms might be expected to divert from what the theory of the firm stipulates. For example, because of risk and uncertainty farmers might not have a profit maximization goal but rather seek to minimize risks and maintain food security. Modifications and extensions to the theory of the firm would thus be needed to capture agricultural firms' real production processes in any attempt to model aggregate agricultural supply response.

All the above problems have been dealt with in the literature in a number of ways. The generic solution for these problems has been the use of dynamic models in modeling aggregate agricultural supply response.

Most empirical estimations of agricultural supply response are based on the Nerlove (1958) model, which captures the dynamics of agriculture by incorporating price expectations and/or adjustment costs. This model can be extended to include expectational variables other than price to capture imperfect information on these variables. In the Nerlove price expectations model, the desired output X_t^* is a function of price expectations P_t^e so that the supply function can be represented as

$$X_t^* = a + bP_t^e \tag{1}$$

where *b* is the long-run elasticity of output with respect to price. Assuming that price expectations are adaptive, then

$$P_t^e - P_{t-1}^e = \delta(P_{t-1} - P_{t-1}^e) \tag{2}$$

where P_{t-1} is the price in period t – 1. Also assuming that $X_t^* = X_t$ i.e. desired output is equal to realized output X_t in equilibrium and substituting for X_t^* and P_t^e from equation (2) into equation (1) gives (for manipulations see, for example, Lim, 1975)

$$X_t = a\delta + b\delta P_{t-1} + (1-\delta)X_{t-1} \tag{3}$$

This implies that output supplied can be expressed as a function of its own lagged value and price as in equation (3) with the short-run elasticity $b\delta$.

Alternatively, the supply function can be derived from the partial adjustment perspective, i.e. that the actual change in output in one period is a fraction α (such that $0 < \alpha < 1$) of the change required to achieve the desired output X_t^*. Thus

$$X_t = \alpha X_t^* + (1-\alpha)X_{t-1} \tag{4}$$

Assuming that $P_t^e = P_{t-1}$ and substituting equation (4) into equation (1) gives

$$X_t = a\alpha + b\alpha P_{t-1} + (1-\alpha)X_{t-1} \tag{5}$$

Thus the output supplied is expressed as a function of its lagged value and the lagged price, just as in equation (3). For an example of empirical work using the partial adjustment model only see Sharma (1992).

From both equations (3) and (5), the reduced form of the supply function in the Nerlove model is

$$X_t = \beta_0 + \beta_1 P_{t-1} + \beta_2 X_{t-1} \tag{6}$$

As mentioned earlier, most empirical estimates have been based on the Nerlove model. Since only the actual rather than the optimal output is observed in reality, only the reduced form equation (6) or its variation can be estimated. However, McKay et al. (1999) point out that estimating equation (6) makes it difficult to distinguish between δ and α when both adaptive expectations and partial adjustment are present. This implies that the long-run price elasticity cannot be estimated based on the Nerlove model unless assumptions are made about whether the model is a partial adjustment or price expectations model. Therefore, certain arbitrary restrictions often have to be made. Furthermore, the simple adjustment mechanism can be derived from the minimization of a single period quadratic loss function with static expectations. This assumes no forward-looking behavior by agriculture producers. In any case, output adjustment to annual price fluctuations is likely to be small since a strong response may come only if price changes are deemed permanent. The Nerlove model is therefore unlikely to capture the full dynamics of agricultural supply and will thus bias the elasticity estimates downwards (Thiele, 2000).

An alternative to the Nerlove model will be needed. Indeed, a lot of work has been done on estimating the supply response of agriculture with the general finding that its response is inelastic (Bond, 1983; Chibber, 1989; McKay et al., 1999).

However, there has been controversy as to whether aggregate agricultural supply is really not responsive. Schiff and Montenegro (1997) argue that aggregate agricultural supply response to prices is in fact high but that there are other constraints such as financing that hinder this response such that a low elasticity is found. Other authors also assert that aggregate agricultural supply is highly responsive but that low elasticities have been observed because of factor prices adjusting in parallel to output prices. Many methodological questions have been asked about the previously used models and the estimation techniques applied. These questions range from whether the estimates for forecasting supply response are reliable to whether the estimates are valid. For instance, the major criticism of time series estimates of aggregate agricultural supply response has been that estimates are drawn for a given price regime and thus mainly reflect short-run variations in prices. Given that agriculture relies heavily on a fixed input, land, it is unlikely that aggregate agricultural supply will respond to short-run fluctuations, with the result that time series estimates are biased downwards.

In response to these criticisms we note that for our study we are not likely to be criticized on the basis of financial constraints, given the huge financial support that the Agricultural Financing Corporation of Zimbabwe extends to smallholder farmers (Muir-Leresche & Muchopa, 2006) and that the financial sector extends to commercial farmers. With respect to the argument of input prices adjusting in parallel to output prices, the data for Zimbabwe indeed shows that domestic fertilizer prices were below their import parity during the periods of agricultural price controls. Including input consumption in the estimated supply equation should isolate this bias. As for the time series nature of our study, we use data that spans different pricing regimes, thereby lending credence to the validity of the elasticity estimates for forecasting the effects of prices changes on aggregate agricultural supply.

4. Methodology

4.1 Empirical estimation

In the light of new developments of econometric techniques that can estimate distinct short-run and long-run elasticities, it is worth answering some of the methodological questions raised in the early literature on aggregate agricultural supply response. This paper estimates the responsiveness of aggregate agricultural supply response to price changes by applying appropriate time series techniques and using data spanning different pricing regimes. The study uses cointegration analysis, which only requires a co-movement of agricultural supply and price in the long run.

In any error correction model (ECM), cointegration analysis offers a method of obtaining distinct estimates of both the long-run and short-run elasticities. Nickell (1985) shows that the ECM can be derived from the minimization of inter-temporal quadratic loss function, thus incorporating forward-looking behavior by agricultural producers. This approach has been used to estimate the aggregate agricultural supply response for Tanzania (see for example McKay et al., 1999).

This paper improves on the methodology used by McKay et al. (1999) by using a relatively recent cointegration technique and by further highlighting the fact that estimating the aggregate agricultural supply response to prices may produce biased estimates if the possibility of reverse causality is not taken into account, as is often the case in single equation time series estimation.

The most widely known single equation approach to cointegration is the Engle-Granger two-step procedure. This approach has some limitations. Firstly, it ignores short-run dynamics when estimating the cointegrating vector. When short-run dynamics are complex, this biases the estimate of the long-run relationship in finite samples.

To counter this, a test based on the coefficient of the lagged dependent variable in an autoregressive distributed lag framework has been proposed (Banerjee et al., 1998). However, the parameter estimates are only asymptotically efficient on the assumption of weak exogeneity of the regressors. McKay et al. (1999) adopt this approach but there is reason to believe that agricultural prices may not be weakly exogenous, which casts doubt on the asymptotic efficiency and consequently validity of their estimates. Secondly, the procedure assumes that only one cointegrating vector exists, which leads to inefficiency in estimation in the event that more than one cointegrating vector actually exists.

The Johansen estimation procedure deals with this problem but, like the Engle-Granger procedure, it presupposes that the order of integration of all the variables is the same and known with certainty. However, the power of the unit root test is low, so it can never be known with certainty whether the postulated order of integration is correct. For a recent African study using the Johansen procedure see Ocran and Biekpe (2008).

The autoregressive distributed lag (ARDL) approach to cointegration proposed by Pesaran et al. (2001) overcomes some of these problems. Firstly, it captures both short-run and long-run dynamics when testing for the existence of cointegration. Secondly, it permits the estimation of cointegration relationships when variables are I(0), I(1) or a mixture of the two, so it is unnecessary to pre-test for the order of integration of the variables in the model provided that the highest order of integration is I(1). Thirdly, it offers explicit tests for the existence of a unique cointegration vector rather than assuming there is only one. Finally, it takes into account the possibility of reverse causality (i.e. the absence of weak exogeneity of the regressors), thereby ensuring that the parameter estimates are efficient and consequently valid. The interested reader is referred to Pesaran et al. (2001) for a detailed explanation of the ARDL approach.

4.2 Data

The data used to estimate the aggregate agricultural supply response was obtained from Zimbabwe's Central Statistical Office's publication, the Compendium of Statistics 2000 (CSO, 2001), and the Government of Zimbabwe's publication, the Agricultural Sector of Zimbabwe Statistical Bulletin (GoZ, 2001). Data on the agricultural sector in Zimbabwe has not been regularly released since the beginning of the so called 'fast-track' land reform program in 2000. Consistent yearly data on agricultural production and prices is available from 1970 to 1999, after which it becomes erratic. Thus, we use a time series with 30 observations. During this period, there was variability in the price data. The estimates are therefore suitable for inferring the long-run relationship between aggregate agricultural supply and prices. The key variables of interest are aggregate agricultural production (a variable named *Output*), which we use as a proxy for supply, and prices (a variable named *Price*) in Zimbabwe. These variables are computed from data for the major crops, namely maize, cotton, tobacco, wheat, coffee, groundnuts and sorghum.

Since agricultural production volumes and prices are available only for individual crops, issues of aggregation arise. The aggregation method adopted is based on equal weights to each crop since the units of measurement for each of the crops are the same, i.e. production output in tons and prices in ZWD million/ton. Moreover, such an aggregation method is appropriate when farmers substitute among crops from one year to another. If fixed weights are used, a substitution from a crop with a higher weight to crops with lower weights is reflected as a decline in output when production might actually have gone up. Thus fixed weights induce substitution bias (Triplett, 1992). Consistent with output aggregation, the aggregate agricultural producer price is similarly based on a simple average of the yearly averages of individual crop prices. This is deflated by the GDP deflator to obtain real producer prices for agriculture. Other variables used in the model are area under cultivation[1] (a variable named *Area*) which is also aggregated using

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[1] Acreage may be used as an alternative response variable especially in individual crop models because acreage is thought to be more subject to farmer's control (Askari & Cummings, 1977). In these instances, independent land area changes would have to be separately accounted for, as Rao (1989) points out. The growth of the agricultural sector takes place in direct competition with other sectors. For this reason, terms of trade for agriculture is the appropriate explanatory variable in aggregate supply response models. In our case, the model will contain own price because of lack of data. We therefore include acreage as an explanatory variable to pick up the difference, i.e. aggregate output may also change because of changes in

equal weights, mean annual rainfall[2] (a variable named *Rainfall*) and annual fertilizer consumption (a variable named *Fertilizer*). All the variables are converted to their natural logarithms.

5. Results

We estimate the supply response using the ARDL approach. Although this approach does not require the pre-testing for unit roots, we follow the general times series procedure and test the variables for unit roots using the ADF (augmented Dickey-Fuller) test with the optimal lag length chosen on the basis of the Schwarz Bayesian Criterion. The unit root test shows that *Output*, *Rainfall* and *Price* are stationary but *Price* has a deterministic trend. *Area* and *Fertilizer* are integrated of order 1. Thus the variables are a mixture of I(0) and I(1) variables. The unit root test results are presented in Table 1.

Table 1: ADF unit root tests (Schwarz Bayesian Criterion used for lag length)

	Levels			First difference		
Variable	**Max lag**	**Test-statistic**	**95% critical value**	**Max lag**	**Test-statistic**	**95% critical value**
*Output**	1	-5.4568	-2.9850			
*Price***	0	-4.9374	-3.6027			
*Fertilizer**	0	-2.7660	-2.9850	0	-6.0099	-2.9907
*Area**	0	-2.4280	-2.9850	0	-5.3301	-2.9907
*Rainfall**	0	-4.2817	-2.9850			

* Specification includes intercept no trend, ** Specification includes intercept and linear trend

The reduced form equation derived from the Nerlove model implies that agricultural supply is a function of its own lagged value and prices. We first estimate this relationship, but in a cointegration framework. We estimate equation (7) below, where ECT is the error correction term similar to that of the Nerlove model but captures both short-run and long-run dynamics as well as incorporating the forward-looking behavior.

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the amount of land under agriculture at any point in time. However, in the Appendix we also include results for the model which excludes acreage.

[2] Since the aggregate agricultural sector in Zimbabwe has mostly experienced droughts rather than floods, we do not follow Mamingi's suggestion (1997) not to include rainfall in a linear way. One option would have been to include rainfall as a dummy variable, taking the value of 1 for optimal rainfall and 0 for non-optimal rainfall.

$$\Delta X_t = \beta_0 + \beta_1 t + \sum_{i=1}^{p} \beta_{1i} \Delta P_{t-i} + \sum_{i=1}^{q} \beta_{2i} \Delta X_{t-i} + \lambda ECT_{t-1} + \varepsilon_t \qquad (7)$$

Firstly, cointegration tests using the bounds test are carried out to establish the existence of a unique cointegrating vector. The conclusions are based on the critical values provided by Narayan (2005) for sample size 30 for the case of unrestricted intercept and restricted trend with two variables (i.e. k=2). When *Output* is the dependent variable, the F-statistic is 4.9872, which is above the upper bound of 4.535 at the 10% level of significance. However, when *Price* is the dependent variable, the F-statistic is 2.1215, which is below the lower bound of 3.770 at the 10% level of significance Therefore, at the 10% level of significance we conclude that there is a unique cointegrating vector and estimate equation (7).

The results from the estimated ARDL(1,1) model show insignificant long-run supply response to price changes. The short-run elasticities for current price (-1.19) and lagged price (1.21) are both elastic and significant; however, the elasticity for the current price is negative, a result similar to that of McKay et al. (1999) in the Tanzanian study. The explanation for this result is that price is endogenous, i.e. price is determined after supply has been observed, which results in low prices during bumper harvests and high prices when supply is low, hence the negative elasticity. This result is consistent with post-planting price announcements, which Zimbabwe tends to use. This result also implies that single equation estimations that fail to take this endogeneity into account provide inconsistent estimates. As mentioned earlier, the ARDL estimates are valid even if regressors are endogenous. Thus in our case we have taken into account the fact that price is endogenous. The significance of the lagged price elasticity reinforces the belief that agricultural producers have adaptive price expectations, which lends support to the Nerlove price expectations model. It should be noted that the table of results for the ARDL(1,1) model has not been presented in the text as below we argue that this model suffers from specification error.

The above Nerlove model can be criticized on the basis of misspecification since it omits other important determinants of output such as rainfall, fertilizer consumption and area under cultivation. Indeed, the test for the exclusion of these variables yields a significant F-statistic of 13.25, showing that the above Nerlove model is misspecified. Therefore, we now estimate an extension of the Nerlove model, where *Rainfall*, *Fertilizer* and *Area* are incorporated. We start by verifying the existence of a unique cointegrating vector again in Table 2, after which we estimate an ARDL for the extended Nerlove model in Table 3.

Table 2: Bounds test for cointegration

Dependent variable	*Output*	*Price*	*Fertilizer*	*Area*
F-statistic[a]	5.1423**	3.2419	2.4824	4.4942

** Significant at 5% level
a-The critical values for case of unrestricted intercept and restricted trend for k=5 are: lower bound I(0)–3.504; upper bound I(1)– 4.743 using Narayan (2005) critical values

Note that the bounds test was not done for the rainfall equation since it is assumed to be weakly exogenous. At the 5% level of significance we conclude that there is a unique cointegrating vector.

The results of the estimated ARDL(1,1,0,0,0), i.e. the extended Nerlove model, are presented in Table 3. Results that exclude area under cultivation are reported in Table A1 in the Appendix.

Table 3: Short-run and long-run elasticities of aggregate agricultural supply

	Short-run elasticities		**Long-run elasticities**	
Variable	**Coefficient**	**Std error**	**Coefficient**	**Std error**
Output(-1)	0.17813	0.14155		
Price	-0.52634***	0.15678	-0.18125*	0.088860
Price (-1)	0.37738**	0.16240		
Fertilizer	0.39257	0.16240	0.47766	0.36748
Rainfall	0.43567**	0.16554	0.53010**	0.21296
Area	0.38804	0.28701	0.47215	0.32054
ECT	-0.82187***	0.14155		
Adjusted R^2			0.72478	
Serial correlation LM test			0.092238[p-value 0.761]	
F (5, 22)			15.2205[p-value 0.000]	

*** Significant at 1% level, ** Significant at 5% level, * Significant at 10% level

The results in Table 3 show that aggregate agricultural supply does not respond well to price incentives because the numerical estimates of supply response parameters are very small. The short-run elasticity with respect to the lagged price variable is inelastic and significant and its magnitude falls in the range of elasticities found elsewhere. Both the short-run and the long-run elasticities with respect to the current prices are inelastic, but the long-run elasticity is only significant at 10% and is smaller than the short-run elasticity. However, both elasticities are negative, which reinforces the endogeneity argument made earlier.

Although the magnitude of its elasticity is small, it seems that rainfall is a key determinant of agricultural supply in the long run. Taking note of this, the authorities could embark on intensified widespread construction of dams to provide water for supplementary irrigation. The error correction term of -0.82187 indicates a high speed of adjustment towards the long-run equilibrium.

In view of the low responsiveness of aggregate agricultural supply to price and rainfall, it should be noted that agriculture also uses land, which is fixed in the short term. One may thus argue that the low aggregate supply response is attributable to lack of technical progress and the slow rate of mechanization of agriculture by small-scale farmers. For the aggregate agricultural supply to be responsive to price, the excess capacity in agricultural land use should be eliminated. In addition, agriculture needs to be mechanized. This does not, however, mean that positive agricultural prices can be neglected for aggregate output growth (though undoubtedly they are essential); it means rather that not too much can be expected from changing the general agricultural price level alone. Instituting price reform measures before some of the necessary non-price supply side reforms have been initiated may be ineffective. A package of changes may elicit a better response from farmers than a price change alone.

6. Conclusion

The study estimated the aggregate agricultural supply response taking into account theoretical and methodological issues raised in earlier literature. The ARDL approach to cointegration was used to estimate the short-run and long-run relationship between aggregate agricultural supply and price. The aggregate agricultural supply does not respond well to price incentives because the numerical estimates of supply response parameters are small. The estimated short-run and long-run elasticities indicate that the aggregate agricultural supply response to price is inelastic, confirming similar findings in the literature. This result means that the agricultural price policy is a somewhat blunt instrument for effecting growth in aggregate agricultural supply in Zimbabwe. The provision of non-price incentives must play a key role in reviving the agricultural sector. The low price elasticity could also be attributable to the presence of hysteresis in the agricultural sector, in which case the aggregate agricultural supply response should be stimulated through technical progress and mechanization of agriculture rather than just by pricing reforms. Given the significance of the rainfall variable, other policies such as irrigation investment are also likely to have a direct effect on aggregate agricultural supply. In fact, a package of changes may elicit a better response from farmers than a price change alone.

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Appendix

Table A1: Short-run and long-run elasticities of aggregate agricultural supply (no *Area*)

	Short-run elasticities		**Long-run elasticities**
Variable	**ARDL(1,1,0,0)**	**ECT**	
Output(-1)	0.26514**		
	(0.12832)		
Price	-0.54553***	-0.54553***	-0.16019
	(0.15892)	(0.15892)	(0.09984)
Price (-1)	0.42781**		
	(0.16088)		
Fertilizer	0.71284***	0.71284***	0.97004***
	(0.18669)	(0.18669)	(0.15609)
Rainfall	0.48235**	0.48235**	0.65639**
	(0.16479)	(0.16479)	(0.22831)
ECT		-0.73486***	
		(0.12832)	
Adjusted R^2		0.71487	
Serial correlation LM test		0.39626[p-value 0.529]	
F (5, 22)		17.9265[p-value 0.000]	

Note: Standard errors are in brackets
*** Significant at 1% level, ** Significant at 5% level, * Significant at 10% level