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Full Length Research Paper

Supply response of beef farmers in Botswana: A Nerlovian partial adjustment model approach

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In this study, an attempt has been made to examine the supply response of beef farmers in Botswana by using the Nerlovian partial adjustment model. The short run price elasticity was 1.511 while the long run elasticity was 1.057. This is a clear sign that price policies in Botswana are effective in obtaining the desired level of output for beef. Moreover, in the future, price increase need to be adopted as a strategy for improved cattle supply. Emphasis should also be given on extension services with a view of promoting cattle farming as a commercial farming. The promotion of cattle farming for commercial purpose should be supported with a strategy by which farmers change their attitude of oxen production to weaner production. The speed of adjustment, however, was relatively very slow at 14% per period. This slow adjustment perhaps tells that Botswana beef farmers, who are predominantly subsistence, may not be having enough capacity (in terms of resources and technology) to immediately increase beef production when economic environment improves in their favour. This situation can be improved if future government intervention is geared towards improvement of current technology of using communal grazing and indigenous breeds. The government also needs to strengthen its extension services to educate the farmers on new technologies of beef production.

Key words: Supply response, beef, Nerlovian partial adjustment.

INTRODUCTION

Agriculture remains the critical source of livelihood for most people in Botswana. In 2003/2004, agriculture contributed 2.3% of the GDP, out of which about 70 to 80% was attributable to cattle production (BEDIA, 2007). By 2004, beef exports amounted to 284 Million (Pulas), approximately 1.7% of total exports of 16.2 Billion (Pulas) (Jefferis, 2005). Notwithstanding this contribution, cattle production remains an important factor in the rural economy as a source of income, employment and investment opportunities. It also has strong linkages with the rest of the economy as a supplier of inputs for meat processing, leather and other industries.

Beef is Botswana's only agricultural export to the European Union (EU). The industry benefits greatly from Continuo preferences which give the country significant competitive advantage over other exporters of beef to the EU (Meyn, 2007). According to Meyn (2007), the country is not a globally competitive beef exporter; Botswana is currently only able to supply markets that have both a high protection degree and a high price level. Both criteria apply to the EU market and the EU's recent offer of duty and quota free market access has further contributed to its attractiveness as export destination.

In 2007, the cattle population in Botswana fluctuated between 2.5 and 3 million (BEDIA, 2007). Despite this seemingly high number of cattle, the off take rate, especially to the Botswana Meat Commission (BMC) which is the chief buyer of beef cattle in Botswana, had been declining over the years. The low off take rate had been attributed mainly to low producer prices. This resulted in excess capacity at the BMC and a huge

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supply deficit to the EU. Cattle in Botswana are kept under two production systems, that is, the traditional (communal) and commercial systems. Currently, the traditional system accounts for approximately 80% of the national cattle population, while the commercial system accounts for only 20% (BEDIA, 2007).

According to Jefferis (2007), the government of Botswana discussed the issue of profitability of cattle farming by cattle producers. The government attempted to provide a market-related price assuming that higher prices will contribute to restoring the viability of the beef and cattle sector by stimulating increased production through improved productivity and higher off take, and thereby addressing the low throughput problem. However, the fact is that producer price increase will help to partially address the problem. It is imperative that the government of Botswana should also come up with strategies that allow cattle producers to reduce the unit cost of producing cattle.

Regardless of the government's intention and plan aforementioned, Botswana's cattle and beef sector has still performed poorly and has not fulfilled its potential as a contributor to economic growth and development, especially in the rural areas. The BMC has never been able to meet its quota of 19 000 tonnes of beef to the European Union (EU), despite being cushioned by the Continuo agreement against price competition from more efficient beef producers like Brazil. As afore indicated, recent discussion by the Botswana government focuses on restructuring the industry and improving its competitiveness through an increase in prices to match those in the region, in the expectation that farmers would respond positively to this price incentive by raising productivity and production levels. The effectiveness of such an idea depends on the responsiveness of farmers to price incentives. Available literature also suggests that non-economic factors such as cattle numbers (inventory), rainfall and technology have a great influence on the supply of cattle for slaughter. Therefore it would be of great interest to find out how responsive Botswana farmers are to variations in these factors. The present study is an attempt to estimate the current long and short run supply elasticities of beef in Botswana.

MATERIALS AND METHODS

Sources of data

Historical time series data for the period 1993 to 2005 was used in this study. We have attempted to include data for recent years but time series data for the years 2006 to 2009 were mostly incomplete and unreliable. Therefore, data on domestic producer prices, annual precipitation, chicken output, cattle inventory (population), annual throughput (number of cattle sold yearly), and annual inflation rate as measured by consumer index were obtained from various sources (Botswana Meat Commission, 1994, 2006; Ministry of Environment, Wildlife and Tourism, 2010; Ministry of Agriculture, 2010; Ministry of Finance and Development Planning, 2010).

As can be seen from Table 1, for the thirteen years under study, cattle population has been fluctuating at around 2.3 million. There has not been any significant increase in cattle population except in 2002 where the population went slightly above 3 million. The 3.06 million cattle in 2002 could be attributed to the good rains in the years 2000 and 2001, whereas the 1.82 million in 1993 could be due to the 1992 drought. This stagnation in cattle population could be attributable to the fact that most farmers use communal areas for grazing. The use of communal grazing areas means that the stocking rate is not controlled and quite often, the carrying capacity of these areas is exceeded, resulting in overstocking and reduced cattle productivity. The traditional sector is usually characterised by low productivity, in the form of low calving rates, low off-take rates, and high death rates compared to the commercial sector. Calving rates in the traditional sector average around 50%, compared to 60 to 80% in the commercial sector, while off-take rates of 7 to10% occurred in the traditional sector compared to 15 to 20% in the commercial sector (Jefferis, 2005). Moreover, much of the grazing land is taken by the rapidly growing villages and towns, as well as game reserves and national parks and this situation has squeezed the grazing land even further.

Analytical technique

Supply response is used as a tool to evaluate the effectiveness of price policies in the allocation of farmer's resource and estimates of supply responsiveness provides useful guidelines to the formulation of economic policy. The price policies have long formed the basis of farm decisions in majority of the least developing countries. It provides framework for adjusting production for optimum resource employment with the objective of promoting economic development. Also, research on supply response is believed to help improve the understanding of the price mechanism. Besides prices, there are various other non-price factors such as weather, irrigation, technology, etc., that also influence supply. The knowledge of supply response greatly helps in farm decisions in the allocation of resources in the right direction. It can also help planners and policy makers to allocate and achieve productions targets in long term planning. The supply response equations can be used to forecast the agricultural supplies in the future. This requires regular agricultural supply response analysis periodically for improving the reliability of supply parameters, which are the foundations of agricultural policy. Therefore, a thorough knowledge of the supply response of food and the implications of policies will be useful for planning food production and the all-round development of the country. For this study, the Nerlove partial adjustment model is used.

The Nerlove's partial adjustment model

Micro-economic theory suggests that the main determinant of the supply of a product is its own price, that is, for this study, the domestic price of beef. Economic theory further suggests that major shifters for beef production and supply are the prices of competing outputs and the prices of inputs. For the beef sector of Botswana, the major competing product is poultry.

A suitable econometric model for the analysis of agricultural supply response based on time series data has been developed by Nerlove (1956) and Nerlove and Bachman (1960). According to McKay et al. (1999), the Nerlove Supply Response Model (NSR) allows explaining dynamic optimization behaviour of farmers, their decisions and their reactions to moving targets. The Nerlove Supply Model is a partial adjustment supply response model, dynamic by nature, heterogeneous by commodity structure, and econometrically estimated by method. It is an "adjustment "model, because according to the assumption one can see in equation (1), producers adjust output Y_t to the desired or optimum level, Y_t^*.

Table 1. Time series data on Botswana's livestock sector.

Year	Cattle Population in millions	Deflated producer prices in (P/ kg)	Average annual rainfall in 100 mm	Number of cattle sold per year in 100 thousands	Annual chicken output in 1000 tons	Annual inflation rate (CPI)
1993	1.82	4.17	3.76	2.31	6.16	14.4
1994	2.30	4.55	3.15	2.06	4.61	10.6
1995	2.53	4.62	4.13	2.26	7.85	10.5
1996	2.25	4.23	5.02	1.01	7.72	10.1
1997	2.21	4.17	5.08	2.43	11.85	8.9
1998	2.34	4.78	4.50	2.10	15.46	6.5
1999	2.58	4.65	3.59	2.66	17.22	7.8
2000	2.10	4.52	6.67	2.14	27.95	8.5
2001	2.47	4.45	5.51	1.81	32.50	6.6
2002	3.06	4.62	2.90	2.08	38.96	8.0
2003	2.02	4.70	3.04	2.42	57.30	9.2
2004	2.15	4.52	5.04	1.84	64.32	7.0
2005	2.07	4.35	3.87	1.60	40.00	8.6

Source: Cattle population, chicken output and Annual Sales: MoA (2010), Prices: BMC (1994, 2006), Rainfall: MoEWT (2010), CPI: MoFDP (2010).

The economic unit to which Y_t* refers may not always be able or willing to make the transition to the desired level instantaneously; thus, if Yt* is a desired number of livestock, this optimal level may not be attained instantaneously because of cost and technology level. Hence, the observable level of the variable may reflect a partial adjustment of the economic unit from current to optimal levels (Dhrymes, 1981):

$$Y_t - Y_{t-1} = \delta\,(Y_t^* - Y_{t-1}) \quad (1)$$

Where, δ is the long-run elasticity of output with respect to price. In other words, the change in output between the current and previous periods is only a proportion of the difference between the optimum level and last year's output. The parameter δ is the adjustment coefficient and its value lies between zero and one. The restriction placed on the parameter δ in equation (1) is both intuitive, and theoretically sound. If δ = 1, it implies that producers are able to fully adjust to supply and demand shocks in one period and $Y_t^* = Y_t$. If δ = 0, it implies that there is no adjustment $Y_t = Y_{t-1}$. An estimate of δ close to one implies almost immediate adjustment; a low δ implies a very slow adjustment to changes in exogenous variables (Griliches, 1959).

The Nerlove Supply Response model, additionally to the adjustment component, also includes another assumption, the so called "price expectations component":

$$P_t^* - P_{t-1}^* = \delta\,(P_{t-1} - P_{t-1}^*) \text{ and } \delta\,[0, 1] \quad (2)$$

The price expectations component, equation (2), consists of the idea that each year, farmers revise the price they expect to prevail in the coming year in proportion to the error they made in predicting price in the current year. Thus, the price expected in the current year is denoted by Pt*, the price expected the previous year by Pt-1*, the actual price the previous year by Pt-1, and the proportion of the error by which farmers revise their expectations, by a constant δ, which lies between zero and one.

In summary, of all the econometric models used to estimate agricultural supply response, the Nerlovian partial adjustment model (Nerlove, 1956) is considered to be one of the suitable model as judged by a number of studies which utilized this approach (Dhrymes, 1981; Braulke, 1982; Hallam, 1990; McKay et al., 1999; Thiele, 2000; Gujarati, 1995; Belete, 1995; Leaver, 2004; Seay et al., 2004; Kennedy, 2008; Ocran and Biekpe, 2008).

The structural partial adjustment model for this study is presented as follows:

$$S_t = f\,(Pb, C, TE, I, R) \quad (3)$$

Where: S_t =is the number of cattle sold for slaughter in year t; Pb = producer price of beef; C = Chicken output (proxy for chicken price); TE = time trend (proxy for technology); I = inventory (population) of beef cattle; R = rainfall in mm.

The estimation equation is as follows:

$$S_t = \alpha\delta + \delta\beta_1 Pb_{t-1} + \delta\beta_2 C_{t-1} + \delta\beta_3 R_{t-1} + \delta\beta_4 TE_{t-1} + \delta\beta_5 I_{t-1} + (1-\delta)\,S_{t-1} + \delta U_t \quad (4)$$

$$S_t - S_{t-1} = \delta\,(S_t^* - S_{t-1}) \quad \delta \in [0, 1]$$

Or

$$S_t = (1-\delta)\,S_{t-1} + \delta\,S_t^*$$

Where: S_t: is output (number of cattle sold for slaughter) at

Table 2. Regression results (Nerlove partial adjustment model).

Variable	Coefficient	Std. error	t-statistic
Constant	-0.157	2.2	-0.071
Current price	1.511***	0.429	3.519
Lagged rainfall (Lr)	-0.288***	0.089	-3.227
Lagged time (Lt)	0.295***	0.092	3.198
Lagged chicken output (Lc)	-0.053***	0.016	-3.378
Lagged Inventory (Li)	-0.955**	0.355	-2.689
Lagged sales (Ls)	-0.857****	0.192	-4.457

Dependent variable: cattle sold for slaughter; ****, ***, **: Significance at 1, 2 and 5% respectively. Adjusted R^2= 0.753; Durbin-Watson statistic = 2.577; Durbin- h statistic = - 1.021.

time $_t$; S_{t-1}: is output at time $_{t-1}$; S_t^*: desired output level; δ: is the coefficient of adjustment.

To make sure that our econometric approach is the correct approach, we have carried out the unit root test for stationary (to check if the variables are stationary). Thus, the test for unit roots is futher discussed.

Test for unit root nonstationarity

A time series variable is stationary if it does not have an upward or downward trend over time. Economists normally focus on one type of nonstationarity, that is, the unit root nonstationarity (Koop, 2009). Where $Y_t = α + ΦY_{t-1} + e_t$, if Φ =1, then Y has a unit root and it is nostationary. If IΦI < 1, then Y is stationary. If Y has a unit root, the value of Φ will not decrease as the lag length increases, and will also have a long memory, and as a result, will exhibit a trend, especially if α is nonzero (Koop, 2009). Koop (2009) also states that if Y has a unit root, then ∆Y will be stationary, hence a series with unit root are often referred to as differenced stationary series. If α = 0 and Φ =1, the new value of Y differs from the preceding value by the error term, and in this case, Y is called random walk because the values of Y over time will consist of random changes, since the error term is random (Halcoussis, 2005; Koop, 2009). If Y is non-stationary, it does not move back and forth around a constant mean, it drifts away over time. For Y to be stationary, the value of Φ must lie between -1 and 1 (Halcoussis, 2005). The most common unit root test is the Dickey-Fuller test, which was developed by statisticians Dickey and Fuller.

The Dickey- Fuller test

It assumes the form $Y_t – Y_{t-1} = B_0 + B_1 Y_{t-1} + e_t$. The dependent variable is the difference between the current and the preceding values of Y and the explanatory variable is Y lagged one period. After running the mentioned regression, one tests for the null hypothesis of the form H_0: $B_1 ≥ 0$ versus the alternative hypothesis of H_1: $B_1 < 0$. This is a one sided test. If B_1 is equal or greater than zero, then Y is nonstationary and H_0 is accepted. If the Dickey-Fuller test rejects the null hypothesis, then we can assume that Y is stationary (Halcoussis, 2005). The critical value for the Dickey-Fuller test at 1% error level is -3.75 whereas the calculated (t-statistic) value is -3.975 which is greater in absolute terms. The null hypothesis H_0: $B_1 ≥ 0$ is rejected. We can then assume that Y is stationary. We are 99% (using the t-statistics) confident that B_1 is not equal or greater than zero:

$$∆Y = 2.578 - 1.259Y_{t-1} + e_t \quad (5)$$
(0.675) (0.317)
[3.818] [-3.975]
R^2 = 0.574
F- Statistic = 15.797

Where figures in the parentheses are standard errors and figures in brackets are the t-statistics.

This test is equivalent to testing for the hypothesis H_0: Φ = 1 against the alternative hypothesis H_1: Φ < 1 in the autoregressive equation $Y_t= α + ΦY_{t-1} +e_t$ in equation (5).

The other alternative Φ > 1 is not considered because that will make the model explosive, which is unlikely in economic time series (Ramanathan, 2002). So, accepting alternative hypothesis H_1: $B_1 < 0$ is equivalent to accepting H_1: Φ < 1 which signifies no evidence of unit root nonstationarity since $Φ = B_1 - 1$.

RESULTS AND DISCUSSION

The regression results are presented in Table 2. The estimation results of the regression are discussed thus.

As can be seen from Table 2, farmers in Botswana take into consideration current price as opposed to previous year (t-1) price when making marketing decisions.This scenario is contrary to available economic theory as Cobweb models stipulate that expectations are based on lagged prices by only one time period. The Nerlove’s adaptive expectation model on the other hand suggests that in agricultural markets, expected prices are based on a weighted sum of past prices, in which weights decline as one goes back in time. This perhaps suggests that only information from past prices is taken into account when making production decisions and not when making selling decisions. Some economic commentators argue that price in the previous period(s) affects the decision to increase or decrease inventory whereas current price directly influence cattle supply (Ospina and Shumway, 1979).

When lagged price is included in the analysis, we found unexpected result. The coefficient of lagged price is neither significant nor economically plausible as it gives a negative sign. This situation forced us to omit lagged price variable from the analysis. The unexpected result probably suggests that, rearing cattle in Botswana is rather a cultural activity than a business activity. Farmers do not necessarily plan to sell, they sell only when conditions are good, and therefore, they do not consider price in the period t-1. The positive relationship between current prices and the number of cattle sold is an economically acceptable response. The result from the regression indicates that in the short run, a 1% increase in the price of beef cattle would lead to a 1.5% increase in the cattle supply. This result shows that farmers in Botswana would sell more cattle immediately when producer prices are increased and the magnitude of the short run elasticity shows that farmers are reasonably responsive to changes in current prices. As can be seen from Table 2, a 1% increase in cattle population would lead to a 1% decline in the number of cattle sold. This could be due to the fact that traditional farmers in Botswana view cattle as a store of wealth rather than a commercial activity. They probably derive more satisfaction from the cattle numbers than the money they make from selling cattle. Cattle numbers in rural communities are a source of social prestige, that is, the more cattle one has, the more the cattle farmer is respected by the society, and the less likely the cattle farmer will be willing to sell.

When rainfall increases by 10%, the number of cattle sold decrease by 2.9%. This negative relationship between rainfall and the number of cattle sold was unexpected. This is, perhaps, high levels of precipitation are known to improve cattle conditions as both grazing and water would be in abundance, thus increasing chances of fetching better prices. Moreover, in Botswana, this result should not be surprising since subsistence farmers usually subsist on both crops and animals. More rainfall means improved harvest to the subsistence farmer and reduced requirements for money. Cattle are usually sold to meet monetary requirements such as food, but when food is plenty, there is no need to sell more cattle. Again, when cattle are in good conditions, they fetch better prices to a subsistence farmer and this means fewer cattle will be sold to meet monetary requirements. The negative relationship between rainfall and cattle sales reflects that farmers would sell more cattle during the period of low rainfall; this is quite intuitive because Botswana is a semi-arid country with erratic rainfall, resulting in sporadic droughts. So, during the times of low rainfall, farmers would sell more cattle to avoid huge losses during the drought period. This trend was confirmed by BMC (2007) when it observed that good rains sometimes have an inverse relationship with supply and that drought affected cattle sales positively as farmers would off-load their cattle to escape drought. Lastly, crop harvest is very poor when rainfall is poor and the monetary requirements are high.

The time variable which was used as proxy for technology showed a positive relationship with the number of cattle sold. This was expected because technological advancement is expected to increase both production level and efficiency. From the regression results, a 10% increase in technology would lead to a 3% increase in the number of cattle sold. The low parameter of time may perhaps suggest that the available technology is not fully utilized and the adoption rate of new technology may be so low to the extent that it does not have much impact on cattle supply. The other reason could be that the available technology is not suited to the subsistence farmers, probably in terms of complexity and affordability. The other argument may be that the extension service might not be having enough capacity (in terms of resources) to ensure effective technological transfer, especially that most of the farmers are deep in the rural areas.

There is a negative relationship between previous and present year supply. When the previous year supply or sales increase by 10%, current year supply declines by 8.6%. This behaviour could also be attributed to the subsistence nature of traditional farmers. If they sold more cattle the previous year, they are likely to need less money in the current year to meet their basic needs. BMC (2007) postulates that the negative relationship between current and previous year supply is due to the fact that farmers take some time to re-build their herds following high off-take rate the previous year.

The negative relationship between chicken output and cattle supply seems normal. As expected, demand for beef would go down when chicken prices decline, since chicken is a strong substitute for beef. A 10% increase in chicken output led to a 0.5% decrease in the number of cattle sold. The small coefficient for chicken output perhaps suggests that, although domestic demand for beef would decline, the export market would still be available to absorb the shock.

The coefficient of adjustment, that is, the speed at which farmers adjust from the previous output (supply) to the desired equilibrium, is 0.143. According to Hallam (1990), a coefficient of adjustment close to zero implies a slow adjustment to changes in exogenous variables. Therefore, the adjustment coefficient of this magnitude implies that beef farmers in Botswana adjust slowly to changes in both economic and technical factors. This means that farmers eliminate about 14% of the difference between the previous and the desired supply in one year. This low adjustment coefficient perhaps tells us that when producer price increases, farmers cannot immediately switch from other sectors of the economy to cattle farming. This is because unlike manufacturing, the time lag between the decision to produce and marketing cattle is quite long, so this may discourage more farmers from venturing into the beef business.

Based on the analysis of the elasticities, price elasticity of supply in the short run seems reasonably high at 1.511 and this means that a 1% increase in the producer price of beef would lead to a 1.5% increase in cattle supply, that is, when other independent variables are held constant at their sample mean. Since the value of the coefficient of elasticity is greater than unity, it could be said that in the short run beef cattle supply is elastic to variations in producer prices. The long-run price elasticity is 1.057. This implies that, in the long run when most or all of the factors that influence supply of cattle have changed, the beef farmers in Botswana would become somewhat responsive to producer prices. This nearly elastic response to price shocks is, however, contrary to what Muchampondwa (2008) found in Zimbabwe, and what BIDPA (2006) found in Botswana. Nevertheless, on the basis of results from our analysis, in Botswana, cattle supply in the short run seems to be inelastic and hence somewhat insensitive to variations in the following factors: rainfall (-0.288), chicken output (-0.053), time (0.295), cattle population (-0.955) and cattle sales (-0.857). This is so since short run elasticities (as afore indicated) for all these factors are less than unity. In the long run elasticities for time trend- proxy for technology (2.06), inventory -population of beef cattle (-6.68), and number of cattle sold for slaughter (-5.99) are greater than unity while elasticity for chicken output – proxy for chicken price (-0.37) and rainfall (-0.201) are less than unity. The elastic long run responses to variations in time, inventory and cattle sales may be due to the fact that in the long run, famers will have more time to work on these changes including increasing their productive capacity.

Conclusion

The primary objective of this study was to determine whether beef farmers in Botswana do respond to price incentives. According to the result from the regression analysis, cattle supply in Botswana is elastic to variations in cattle producer prices. From the results, one can suggest price increase as one of the ways of improving beef cattle supply since farmers respond positively to price changes. On the other hand, elasticity estimates of chicken output, rainfall, cattle inventory, time trend and lagged sales were found to be less than unitary, an indication that cattle supply is inelastic to these factors. In the long run, cattle supply is elastic to all the factors except chicken output.

From this empirical analysis, it is evident that Botswana farmers take into account all variables included in the model when deciding on the sale of their cattle. One other important point to note is that all of the variables except beef price and time trend are inversely correlated with cattle sales. This perhaps implies that when the variables increase, cattle sales decrease. It is also worth noting that although farmers would respond positively to price increase, they can only cover 14% of the desired level of output or supply in a year. This slow rate of adjustment could be attributed to the fact that farmers do not make use of modern technology such as artificial feeds and improved breeds with fast growth rates.

This scenario calls for the government to assess the available technology if it suits the traditional farmers in terms of complexity and affordability. The government also needs to strengthen its extension services (perhaps the farmers are reluctant to adopt new technology) and thereby educate the cattle farmers about the advantage of the new technology. To improve the productivity of the rangelands, the Botswana Government will have to seriously consider restructuring the traditional system in view of doing away with communal grazing. Traditional farmers mainly raise the indigenous Tswana breed which is known for its poor traits such as poor growth rate and low level fertility. So, if farmers are to improve the speed of adjustment, they will have to improve their breeding stock so as to enhance the aforementioned traits.

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