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Economic returns from investment in beef cattle improvement research in South Africa

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ABSTRACT
The national beef cattle improvement scheme was introduced by the South African government with the objective of improving the biological and ecological efficiency of beef production through genetic improvement and enhanced cattle management practices. This has been achieved through various structural and technological changes targeted at increasing beef production and promoting sustainable production systems. Despite the technical success of the programme, and the substantial investment made into it, there is limited information on the returns to investment made in the beef improvement scheme in South Africa. Using time series data from 1970–2014, the study uses an econometric approach modelled through the Almon Polynomial Distribution to estimate the lead period and rate of return from investment in beef cattle improvement research. The lag effect and absence of a lead-time suggest that research impacts beef production in the current year of investment. A marginal rate of return of 32 per cent implies that South Africa received R32 for every rand invested towards the scheme. This suggests that the research investment is worthwhile and motivates for continuation of the beef cattle improvement research given significant and positive economic efficiency measures.

KEYWORDS
beef cattle improvement; marginal rate of return; livestock; Almon Polynomial Distribution

JEL CLASSIFICATION
C22; O22; Q16

1. Introduction

The beef industry is one of the most important industries within the South African agricultural sector, partly because approximately 80 per cent of the country's agricultural land is not suitable for crop production but can support livestock production (Department of Agriculture, Forestry & Fisheries, 2017). Over the years the industry has maintained second position in terms of contribution to the livestock gross value, first position being held by the poultry industry. During 2015/2016 the gross value of beef production amounted to about R30.6 billion. The beef industry also provides many social and economic attributes to the livelihoods of rural communities in developing countries and South Africa is not an exception. Not only does it generate food and income, but cattle are also valuable assets serving as a store of wealth and security in times of livelihood shock.

Beef cattle farmers in South Africa include commercial beef producers, emerging black beef cattle farmers and communal beef cattle farmers; estimated at 50 000, 240 000 and three million respectively (DAFF, 2016). Out of the 13.84 million head of cattle in South Africa, the commercial sector is estimated to own 60 per cent and the remaining 40 per cent is owned by both the communal and emerging beef farmers (DAFF, 2016).

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With the increase in population, urbanisation and economic development in developing countries, it is expected that the demand for livestock products will also increase. Scholtz *et al.* (2010a) projects that the world demand for meat is expected to rise by over 200 per cent, from about 229 million tons in 1999 to 465 million tons by 2050. While this presents market opportunities to livestock producers it is, however, a challenge, since South Africa is not self-sufficient in beef production (DAFF, 2016). Efforts to increase beef production and to create a sustainable industry have been in place since the 1930s through the establishment of the Meat Board, which mainly regulated the marketing environments (National Agricultural Marketing Council, 2001). However, changes in the marketing structure alone could not have been sufficient to bring the industry to where it is today.

The South African government recognised the importance of livestock improvement and the value of a reliable registry of an animal's pedigree and, hence, facilitated livestock improvement research. This was done through the development of various livestock improvement schemes with an objective to improve productivity (Mokoena *et al.*, 1999).

2. Beef cattle improvement research in South Africa

The history of cattle improvement research can be traced to the eighteenth century after cattle breeders realised the importance of heredity in the improvement of livestock, which resulted in imports of purebred animals from other countries. As the export business began to flourish, a need was felt for proper registration of animals' pedigree (Barnard 2007). Beef cattle improvement research was formally recognised in South Africa in the 1950s and was done through performance testing; a process of recording the performance of the animal of interest and using this data to make sound decisions regarding breeding (Willis, 1991). Currently, there are two performance testing systems operating in South Africa namely: The BREEDPLAN Model and the National Beef Recording and Improvement Scheme (Schutte, 2007). Both systems use the world's most advanced genetic evaluation system called the Best Linear Unbiased Prediction (BLUP) to produce Estimated Breeding Values (EBVs) of recorded cattle for a range of important production traits such as weight, carcass and fertility (Bergh, 2010; BREEDPLAN, 2016). This study focusses on the National Beef Recording and Improvement Scheme.

The National Beef Cattle Recording and Improvement Scheme was launched in 1959 by the Department of Agriculture at Irene Research Campus (Mokoena *et al.*, 1999) and remained under its management until 1997 when it was transferred to the Agricultural Research Council (ARC) (Bergh, 2010). The scheme was heavily reliant on public funding through parliamentary grants until it was transferred to ARC's management. From 1997, as part of the ARC's target to reduce its reliance on government funding, the scheme was also funded from external sources which included income generated from royalties, interest on investments, donations, product sales and contract research (Liebenberg *et al.*, 2007).

The mandate of the scheme was

> … to record and supply the beef industry with objective performance information such as rate of reproduction, growth rate, weaning weight and ease of calving, so as to improve the biological and ecological efficiency of beef production through genetic improvement and enhanced cattle management practices.
>
> Scholtz *et al.* (2010b: 55).

While this performance information is used for selection purposes (e.g., breeders are informed of which bulls to use for breeding purposes or slaughter), it also serves as a valuable marketing tool as buyers are willing to pay more for performance-tested animals (Bergh, 2010). Over the years, the scheme succeeded in developing into a technically sound, popular and well organised programme with significant impact on the beef cattle industry. The results of traits that have been evaluated within the beef scheme show an increase in the 205-day weight for the period 1980/1984 to

2005/2008 by about 10 per cent and a decrease in the inter-calving period by 26 days on various cattle breeds registered within the scheme (Bergh, 2010).

Although substantial investments have gone into the programme, it is not clear what the return on the investment has been, and there is no up to date economic impact assessment of the scheme to aid decision making. The only study conducted to estimate economic returns on research investments on various livestock improvement programmes (1970–1996) was by Mokoena *et al*. (1999). The current study builds on this earlier work and estimates the economic returns to the beef improvement scheme in South Africa from 1970 to 2014. The study adds value to this earlier work in several ways. Over time, there have been changes within the beef scheme such as the development of new technologies and the administrative transfer of the programme to ARC, which could have affected its economic performance. The passage of time has also added substantially to the length of time series since the study by Mokoena *et al.* (1999). Moreover, Hurley *et al.* (2014) highlight that despite a vast body of economic evidence reporting high rates of return to investment in agricultural research and development, growth in public research spending has been declining over the years.

Hence, empirical estimation of the economic returns to the beef scheme can guide evidence-based decision making regarding resource allocation and investments in livestock research and development. Increased investment in livestock improvement research will also likely improve the herd, especially in smallholder agricultural sector, which is critical for facilitating efforts to commercialise livestock production.

3. Approaches to estimate the rate of return from investment in agricultural research

Economists have over time, investigated appropriate methodologies to evaluate R&D activities effectively, building on the concepts of consumer and producer surplus. The commonly used ex-post approaches to estimating rates of return (ROR) can be grouped into two broad groups; the economic surplus and econometric approaches. The economic surplus approach employs a partial equilibrium analysis where benefits of a research project are calculated as the change in producer and consumer surplus with the end product being the average rate of return, also called the internal rate of return (IRR) (Anandajayasekeram and Babu, 2007). In the econometric approach a production function is used to estimate the marginal rate of return (MRR) to agricultural R&D. This is done by allowing research activities to serve as inputs for the production function. The MRR quantifies the returns to the last rand spent on the research project, addressing methodological concerns with the use of the IRR. The MRR has been deemed as a more reliable tool when compared with the IRR (Anandajayasekeram & Babu, 2007; Rao *et al.*, 2012). Whereas the study by Mokoena *et al.* (1999) used the economic surplus approach, this study made use of an econometric approach, defining a production function to estimate the marginal rate of return for R&D investments on beef cattle improvement research.

3.1 The production function approach

In evaluating returns to agricultural research over time, Griliches (1964) proposed the inclusion of agricultural research and development (R&D) extension expenditures, as explanatory variables in an unrestricted Cobb-Douglas production function. Following previous studies such as Townsend and van Zyl (1998), Nieuwoudt and Nieuwoudt (2004) and Karanja (2007), inclusion of R&D expenditures (T) in the production function gives:

$$L_nY = L_n\alpha_0 + \alpha_1 L_nX_1 + \alpha_2 L_nX_2 + \ldots + \alpha_n L_nX_n + \alpha_T L_nT \quad (1)$$

where Y represents output, X_1 to X_n are the respective input variables and a_1 to a_n are the coefficients (elasticities) to be estimated. The coefficient α_T is the output elasticity of R&D and extension expenditures (T). Input variables that can be included in the production function include labour, land, machinery, weather, feed and veterinary services. Feed can further be broken down into purchased feed and grazing. The main challenge with including these variables in the production function is that the data is usually not available for the entire time series.

Some previous studies using the production function approach do not consider weather as an input (Alston *et al*., 1998). The consequence of unmeasured weather influences is that the typical indices of output quantity and productivity fluctuate from year to year. As a result, the true interpretation of indices is masked by weather-related measurement error (Alston *et al*., 1998). In most econometric production studies, the effect that weather has on production is consigned to the error term. If the omitted weather variable is not correlated with the included explanatory variables, then its exclusion will not lead to omitted variable bias. In reality, however, it is not practical to assume that farmers do not respond to weather within the production period, thus it may be worthwhile to account for weather effects explicitly.

Two main weather factors play a critical role in beef production, namely: rainfall and temperature (Robertshaw & Finch 1976; Tacher & Jahnke, 1992). Rainfall affects livestock indirectly as it is via plants that they are later converted into feeds. Heat on the other hand has a direct effect as it affects water balance and food intake.

3.2 Determining the lag structure

Often, a lag exists between the R&D expenditures and productivity growth. A distributed lag structure is often assumed because lagged values of R&D expenditures are likely to be highly correlated, at the same time using too many degrees of freedom in econometric estimation (Townsend and van Zyl, 1998). The distributed lag usually takes form as the inverted V or a second degree Almon polynomial lag (Thirtle *et al*., 2008). The second degree Almon Polynomial lag takes form as an inverted U-shape since it is assumed that the impact of new knowledge arising from research first rises and then falls (Alston *et al*., 1998).

The Almon polynomial lag allows the researcher to capture lagged effects of R&D on productivity change or yields, and to avoid collinearity problems of the unrestricted lag model, hence it is commonly used (Townsend & Thirtle, 2001). Although the specification may require restrictions, the polynomial form is popular because of its empirical simplicity. In order to determine the appropriate lag length in this context, a range of polynomial distributed lag (PDL) models were examined. The second degree polynomial order was a better fit, as compared to the third polynomial degree which was producing models that were not statistically reliable. This is consistent with Thirtle *et al*. (1998) who also indicated the use of a second degree polynomial order to estimate benefits to animal research in ARC.

Various options exist when estimating PDL models, these include a decision on whether to impose constraints on the model or not. Constraint options include equating the far end, near end or both end points of the lag structure to zero. According to Townsend and van Zyl (1998) using restricted models leads to biased estimates of the effects of research spending. To mitigate this problem, the regression was run without imposing any restrictions at first. This, however, presented models whose coefficients were not stable indicating negative and positive impacts of R&D on beef production as well as unstable t-statistic values (values fluctuating between negative and positives rapidly). Scientific evidence has already proven that investment in beef cattle research has been beneficial as measured in terms of the increase in carcass weight. It was thus reasonable to hypothesise from the beginning of the study that the benefits of the scheme are positive and negative estimates were considered as unrealistic. In order to come up with better results, restrictions were then imposed on the polynomial distribution lag specification starting with equating the near end to zero; then the far end and eventually both ends to determine which constraints option yielded better results.

The following equation, estimated by E Views 8 was used to determine the lag structure:

$$\text{WEIGHT}_t = \ln\alpha_0 + \ln\alpha_1 FEED_t + \ln\alpha_2 WEATHER_t + \sum_{i=1}^{n} \beta_t RD_{t-1} + \mu_t \quad (2)$$

where WEIGHT represented carcass weight (output) of the beef production process in year t and being a function of feed quantity consumed by beef cattle; FEED[1], the quantity of feed consumed by beef cattle in year t; WEATHER, the weather index as represented by temperature in year t and $R\&D_{t-12}$,[2] being the research expenditure in year t. The coefficient β is the elasticity of R&D at various lag lengths where n is the maximum lag of R&D that affects WEIGHT. The μ_t term is the residual which accounts for all the deviations in yield not explained by the model. Equation (2) was used to determine the lag structure, which was then imposed on the data and used to calculate a ROR to investments into the beef scheme in South Africa.

3.3 Estimating the marginal rate of return

To estimate the MRR, the lag structure was determined using Almon Polynomial Distribution Lag, which used an equation formulated by the basic production function. Once the lag structure was determined, several formulas were used to calculate the MRR following the procedure in Townsend and van Zyl (1998), Townsend and Thirtle (2001), Anandajayasekeram, and Babu (2007). The lag structure in the polynomial model identified the effects of changes in R&D expenditure on beef production holding all other factors constant. In order to derive a rate of return, the coefficients of the beef cattle improvement research and its lagged variables (also referred to elasticities) were converted into value of marginal products following the procedure in Anandayasekeram and Babu (2007). Each lag coefficient, β_i is the output elasticity of R&D is specified as:

$$\beta_i = \frac{\delta lnOUTPUT_t}{\delta lnRD_{t-1}} = \frac{\delta OUTPUT_t}{\delta RD_{t-1}} * \frac{RD_{t-1}}{OUTPUT_t} \quad (3)$$

To estimate the value of marginal products (VMP), the geometric means of beef production and beef cattle improvement research expenditure for the period 1970 to 2014 were calculated separately. These were calculated following Equation (4) as shown:

$$\frac{\Delta OUTPUT_t}{\Delta RD_{t-1}} = \beta_i \frac{\overline{OUTPUT}}{\overline{RD_{t-1}}} \quad (4)$$

Estimating the value of beef production for the period 1970 to 2014 was the next step. The value of beef production was estimated by multiplying the real average prices[3] of beef with the quantity of beef produced in each year from 1970 to 2014.

Following this was a step involving the estimation of the change in the value of beef production and change in beef production. The change in the value of beef production was estimated by taking the difference between the average of the first five years (1970–1974) and the average of the last five years (2010–2014). A similar approach was used to calculate the change in beef production.

The mean beef production, the change in the value of beef production and the change in beef production were then multiplied with elasticities of each of the lagged research expenditure variable to calculate the value of marginal product for each of the years of the research lag distribution following Equation (5):

$$VMP_{t-1} = \frac{\Delta VALUE_t}{\Delta RD_{t-1}} = \beta_i \frac{\overline{OUTPUT}}{\overline{RD_{t-1}}} * \frac{\Delta VALUE_t}{\Delta OUTPUT_t} \quad (5)$$

The values of marginal products were then used to calculate the MRR to beef cattle improvement research using Equation (6). However, the discount rate had to be calculated first to allow for the long lag between the expenditures and the results. As done in other studies (for example, Thirtle and Bottomley, 1989), the discount rate was calculated based on the number of years of the lagged research variable, i.e., 22 years. This discount rate (*i*) was taken as the reciprocal of the lag length of the cattle improvement research variable (1/22) which is approximately 4.55 per cent. The MRR was therefore estimated as specified below:

$$\sum_{i=1}^{n} \frac{VMP_{t-1}}{(1+r)^i} - 1 = 0 \tag{6}$$

where, *n* is the lag length, and by making *r* subject of the formula, the MRR was calculated.

4. Data description

Time series data covering 44 years from 1970 to 2014 were used. Given that ARC-API is the principal administrator of the research programme, the study only made use of R&D expenditures that were obtained from the institute and South African government expenditure reports prior to 1997 as used in other studies (e.g., Mokoena *et al.,* 1999).

R&D, defined as the research costs, included the actual expenses on staff salaries and benefits; recruitment expenditure; administration and overhead expenditure; and provision for the depreciation of capital assets. These expenses were added together on an annual basis to derive the R&D expenditure series in nominal terms. Historical prices and output data were obtained from the Abstract of Agricultural Statistics (DAFF, 2015). The historical prices of beef and R&D expenditure data were deflated to 2010 prices using the Consumer Price Index as published by the South African Reserve Bank. The data on the quantity of feed consumed by beef cattle was obtained from various sources. These include annual publications by the Animal Feed Manufacturers Association (AFMA) as well as the records of the Department of Agriculture, Forestry and Fisheries.

It was not possible to get data on land used for grazing purposes (this was only obtained for 1991) in this study. We assumed that the state of grazing land would be related to the weather and the amount of purchased feed, both of which were included in the model. Data used to estimate the weather index was obtained from the South African Weather Services and comprised average daily maximum temperature for beef producing regions in South Africa.

A study by Townsend and Thirtle (2001) estimating the rate of return in livestock research used the rainfall index to represent the weather index. For the purpose of this study, maximum temperature was used to compute a weather index. Rainfall was not used in order to avoid correlation between the feed variable and rainfall. Another motivation for using temperature was that it influences the feed conversion rate by livestock. To estimate the weather index, data was obtained from the South African Weather Services. This data recorded average daily maximum temperatures for beef producing regions in South Africa. The annual averages of these districts and towns were then used to compile the provincial average maximum daily temperature. This was in turn used to compile the national weather index for each year from 1970 to 2014 using 1970 as a base year. The indices for the other years were then obtained by measuring each year's deviation from the base year.

Data on labour, land, machinery, feed and veterinary services were not available at national level, therefore a modified production function was used. This was done taking into account the fact that omitting variables can lead to functional form misspecification resulting in biased and inconsistent estimators (Wooldridge, 2013). To mitigate this challenge, the Ramsey Reset test for model misspecification was imposed on the data. The results of the Ramsey Reset test indicated no significant misspecification detected on the function.

5. Results and discussion

One of the greatest challenges encountered when using the production function approach in rate of return studies is econometric problems such as serial correlation that exist due to the time series nature of the data (Anandajayasekeram & Babu, 2007). In order to determine whether any of the classical normal linear regression assumptions were violated, diagnostic tests were conducted on the model. This involved testing for normality using the Jarque-Bera test; heteroscedasticity using White's test; serial correlation using Breusch-Godfrey test; and misspecifications using the Ramsey Reset test. It was observed that none of the normal linear regression assumptions were violated.

5.1 The lag structure

Table 1 shows the regression output model. An adjusted *R*-squared of 0.92 implies that 92 per cent of variation in beef production is explained by the explanatory variables included in the model. A high adjusted *R*-squared has been reported in several studies that made use of the econometric approach such as Townsend and Thirtle (2001) who used the supply response model and reported an adjusted *R*-squared of 98 per cent. Townsend and Van Zyl (1998), Nieuwoudt and Nieuwoudt (2004), Isinika (2007) and Thirtle *et al.* (2008) also used the econometric approaches to estimate the rate of return in investing in various agricultural sectors and reported an adjusted *R*-squared values greater than 70 per cent, with some reaching 93 per cent.

When using a restricted lag structure to model research investments, it is expected that the *t*-statistics remain the same for all lagged variables. Using the rule of thumb, the *t*-statistic of 2.61241 found in this study is statistically significant at 1 per cent level as it is greater than the threshold of 2.576 (Wooldridge, 2013). Similarly, Townsend and van Zyl (1998), Townsend and Thirtle (2001) and

Table 1. Twenty-two year beef cattle improvement research lag model.

Variable	Coefficient	Standard error	*t*-statistic
Constant	−7836886.0	2418574.0	−3.24029
LnFeed	336981.6	55294.4	6.09431
LnWeather	891650.2	526076.0	1.69491
RD	0.00055	0.00021	2.61241
RD(-1)	0.00105	0.00040	2.61241
RD(-2)	0.00151	0.00058	2.61241
RD(-3)	0.00192	0.00073	2.61241
RD(-4)	0.00228	0.00087	2.61241
RD(-5)	0.00259	0.00099	2.61241
RD(-6)	0.00285	0.00109	2.61241
RD(-7)	0.00307	0.00117	2.61241
RD(-8)	0.00323	0.00124	2.61241
RD(-9)	0.00335	0.00128	2.61241
RD(-10)	0.00343	0.00131	2.61241
RD(-11)	0.00345	0.00132	2.61241
RD(-12)	0.00343	0.00131	2.61241
RD(-13)	0.00335	0.00128	2.61241
RD(-14)	0.00323	0.00124	2.61241
RD(-15)	0.00307	0.00117	2.61241
RD(-16)	0.00285	0.00109	2.61241
RD(-17)	0.00259	0.00099	2.61241
RD(-18)	0.00228	0.00087	2.61241
RD(-19)	0.00192	0.00073	2.61241
RD(-20)	0.00151	0.00058	2.61241
RD(-21)	0.00105	0.00040	2.61241
RD(-22)	0.00055	0.00021	2.61241
Adjusted *R*-squared	0.920242		
F-statistic	85.61193		
Prob(*F*-statistic)	0.000000		
Durbin-Watson	1.715789		

Source: EViews output

Thirtle *et al.* (2008) used a restricted lag distribution model in studies involving the UK agricultural productivity, animal health and wine grapes research respectively, and the *t*-statistics of the lagged public research variables were found to be the same.

The coefficients of the research expenditure variable for the regression model are plotted in Figure 1, together with the project investment time in years. In the context of this research, the effects of public investment into beef cattle improvement research are spread over a period of 22 years. Also shown in Figure 1 is the absence of a lead-time, implying that research already impacts beef production in the current year of investment in a positive way. Other rate of return studies that employed the production function approach (e.g., Townsend & Thirtle 2001) have also recorded an immediate impact of research on output. Thirtle *et al.* (1998) also observed that research of a management and extension nature could realise benefits within the first year of the investment being made. However, this is contrary to the assumption by Mokoena *et al.* (1999) of a 10-year lead-time, which unfortunately is not explained in the article.

The lag effect starts at a low level, increasing over the years and reaching a peak from where it begins to decrease. The maximum impact of public investment into beef cattle improvement research is felt in year 11 after the research investment has been made. After year 11 of investment into beef cattle improvement research, the effect starts to decline, although still positive, until year 22 from which the research programme becomes obsolete. This decline relates only to the expenditure in year 0. It is noteworthy to mention that the imposition of restrictions on the polynomial distribution lag could have affected the efficiency of the estimates derived (Townsend & van Zyl, 1998), and could also explain the deviation from the lag of 13 years indicated by Thirtle *et al*. (1998). The lag effect within the context of this study suggests that research responds immediately to some of the needs in the beef industry and continues to do so for several more years to come. This is not surprising considering that ARC-API is, in addition to recording and supplying performance information, also involved in breeding research and some of the work done, which is of a management nature, can realise results within the year of investment (Thirtle *et al*. 1998). Furthermore, administration of the beef scheme is continuously improving thereby contributing to the positive effects associated with the beef cattle improvement research.

5.2 The marginal rate of return from investing in beef cattle improvement research

A marginal rate of return of 31.89 per cent was obtained following the estimation steps described in Section 3.3 and as illustrated in Table 1. Some years of the calculations have been left out to reduce the size of the table.

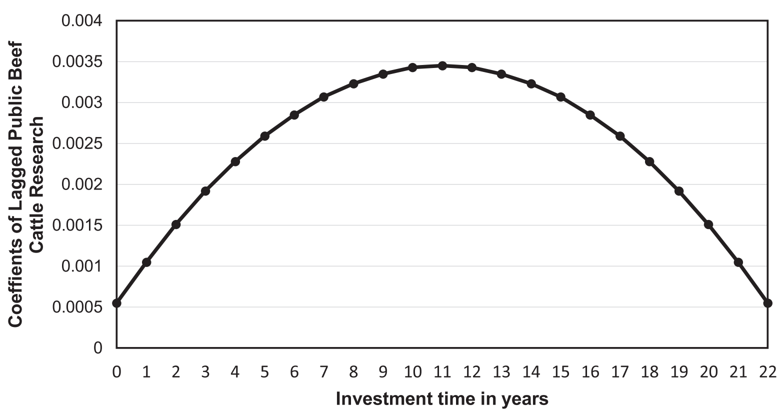

Figure 1. Lag structure of R&D effects on beef cattle improvements research over time.
Source: EViews output.

By making r in Equation (6) above the subject of the formula, the MRR to beef cattle improvement research was estimated as:

$$r = (\sum_{i=1}^{n} VMP_{t-1})^{\frac{1}{i}} - 1 \quad (7)$$

where
$\sum_{i=1}^{n} VMP_{t-1} = 437.50793$ (see Table 2 for estimation of VMP) and $\frac{1}{i} = \frac{1}{22}$
Therefore:

$$r = (437.50793)^{\frac{1}{22}} - 1$$

$$= 1.31893 - 1$$

$$= 0.31893$$

$$MRR = 0.31983 * 100$$

This MRR of 31.89 per cent, suggests that for every R100 increase in investment on beef cattle improvement research, the marginal returns to the beef industry is about R32. These results compare well with other studies showing positive effects of expenditures on beef cattle improvement research in the beef industry and measuring rates of return to agricultural R&D, both in South Africa and other countries (see Table 3). Mokoena *et al*. (1999) estimated the ROR of expenditure on the beef cattle improvement research in South Africa and reported an IRR of 44 per cent. It is expected that an MRR will be lower than an IRR as it tends to overestimate the rate of return (Rao *et al.* 2012).

Table 2. Estimation of VMP.

Coefficient		Geometric mean Q/ Geometric mean RD (A)	Change in value/ Change in output (B)	VMP = Coefficient * A * B
RD	0.00055	0.294282	26976.86	4.3663
RD(-1)	0.00105			8.3358
RD(-2)	0.00151			11.9876
RD(-3)	0.00192			15.2425
RD(-4)	0.00228			18.1005
RD(-5)	0.00259			20.5615
RD(-6)	0.00285			22.6256
RD(-7)	0.00307			24.3722
RD(-8)	0.00323			25.6424
RD(-9)	0.00335			26.5950
RD(-10)	0.00343			27.2301
RD(-11)	0.00345			27.3889
RD(-12)	0.00343			27.2301
RD(-13)	0.00335			26.5950
RD(-14)	0.00323			25.6424
RD(-15)	0.00307			24.3722
RD(-16)	0.00285			22.6256
RD(-17)	0.00259			20.5615
RD(-18)	0.00228			18.1005
RD(-19)	0.00192			15.2425
RD(-20)	0.00151			11.9876
RD(-21)	0.00105			8.3358
RD(-22)	0.00055			4.3663
Sum				**437.5079**

Table 3. Rate of return in livestock research.

Study and year	Country and period	Subject	Approach	ROR (%)
Mokoena *et al*. (1999)	South Africa, 1970–1996	Beef cattle improvement research	Economic surplus approach	IRR: 29.44
Townsend and Thirtle (2001)	South Africa	Livestock research	Econometric approach	MIRR: 18.35
Fox (1995)	Canada	Beef cattle	Econometric approach	IRR: 61.5
Kaliba *et al*. (2007)	Tanzania, 1966–1995	Livestock Research	Econometric approach	MIRR: 29.36
Results from this study	South Africa, 1970–2014	Beef cattle improvement research	Econometric approach	MRR: 31.89

6. Conclusions and recommendations

Beef cattle improvement research has been successful in improving beef cattle performance in South Africa. The study observed a positive and significant rate of return from investing into this research, indicating that the investment is worthwhile and will have an impact in the future; thereby justifying an increase. Also observed in the study were a 22 year lag and a zero lead period. The absence of a lead period and the lag effect revealed imply that research is problem-oriented and there is a short time lapse between investing and obtaining the results.

While scientific evidence provided in this study suggests that the beef scheme has been worthwhile, it will be implausible to conclude that investment in the beef scheme alone will be sufficient to enable the country to meet the local demand of beef in the near future. Various factors affect the beef industry and these would need to be considered before the growth of the industry can be attributed to specific elements. For example, some of the biggest challenges facing the livestock sector are low production levels of the small-scale farmers, lack of disaster management programmes, high feed costs as well as global warming. As a result, for South Africa to be able to meet its local demand for beef, investment will also need to be made in programmes such as drought relief as well as programmes that assist small-scale farmers to achieve high off-take levels like the commercial sector. There is also a need for private stakeholders to collaborate with the government for increasing funding in livestock research.

While the financial records show that investments in the National Beef Scheme have been declining over the years, it is evident that investments made several years ago are still benefiting the beef cattle industry. Positive marginal rates of returns imply that investment in agricultural R&D is worthwhile and justifies continued funding of the beef cattle improvement research. Such investments will have spill-over effects and contribute to efforts to build quality breeds in the smallholder sector and accelerate efforts to commercialise smallholder cattle production in the country. The data problems experienced in this study and similar studies, suggest the need for establishing mechanisms for rescuing, capturing, storage and sharing of information that can be used to evaluate effects of technological interventions in South Africa, and to analyse long-term agricultural productivity. This was the passion of the late Dr Frikkie Liebenberg and should be pursued by the Agricultural Economics fraternity in South Africa for the benefit of the country and to generate evidence-based decision making on agricultural investments.

Notes

1. The feed variable was included in the regression as representing the conventional inputs.
2. The R&D was deflated to 2010 prices using the Consumer Price Index as published by the South African Reserve Bank.
3. Prices were deflated to 2010 prices using the Consumer Price Index as published by the South African Reserve Bank.

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