CATTLE IMPROVEMENT SCHEMES IN SOUTH AFRICA: MEASURING THE RETURNS TO RESEARCH INVESTMENTS

M.R. Mokoena[1], R.F. Townsend[2] and J.F. Kirsten[3]

The rates of returns (RORs) to investments in cattle production research programs were estimated using the Akino-Hayami index-number approach. The RORs to investments in the dairy and beef cattle improvement schemes from 1970 to 1996 were estimated to be 51% and 44% respectively. A simple Benefit-Cost model was used to test the robustness of these results. The estimates derived from this method corroborate the previous result for the dairy scheme while the return to the beef scheme reduced to 29%. The estimated returns from these schemes are higher than the returns from aggregate livestock research, which provides some information for decisions on research funding allocations. Given the nature of this research, future cost recovery measures should be pursued with an increasing share of private sector investment.

BEPALING VAN DIE OPBRENGS OP NAVORSINGSINVESTERING IN VEEVERBETERINGSKEMAS IN SUID-AFRIKA

Die opbrengskoers op investering in veeproduksie navorsingsprogramme is bepaal deur middel van die Akino-Hayami indeksgetal benadering. Hierdie navorsing bepaal dat die opbrengs op investering in die suiwel en vleisbees verbeteringskema van 1970 tot 1996 gelykstaande is aan 51% en 44% onderskeidelik. 'n Eenvoudige voordeelkoste-analise model is ook gebruik om die robuustheid van hierdie resultate te toets. Die resulate wat met hierdie metode behaal is, stem in die geval van die suiwelskema ooreen maar in die geval van die vleisbees skema verlaag die opbrengskoers na 29%. Die opbrengskoers van die individuele skemas is aansienlik beter as die resultate wat bereken is vir die totale spandering op lewendehawe navorsing. Dit is duidelik dat die koste van lewendehawe navorsing voortaan gedeel kan word deur toenemende investering deur die privaatsektor.

1. INTRODUCTION

The livestock sector plays a significant role in the agricultural sector in South Africa. Over the past several decades livestock products accounted for about

[1] *Graduate student, Department of Agricultural Economics, Extension and Rural Development, University of Pretoria and Directorate Marketing, National Department of Agriculture, Pretoria, South Africa.*

[2] *Department of Agricultural Economics, Extension and Rural Development, University of Pretoria and World Bank, Washington, DC.*

[3] *Department of Agricultural Economics, Extension and Rural Development, University of Pretoria.*

40% of the total value of agricultural output which is not surprising as 80% of the agricultural land is not suitable for crop production but can maintain livestock production. Livestock also performs a number of important roles or functions in the lives of rural communities in developing areas. These functions can be categorised into social, economic and cultural roles (Nkosi & Kirsten, 1993). Recent research has shown that economic/commercial objectives are becoming increasingly more important (Steyn & Tapson, 1992; Nkosi & Kirsten, 1993). Several support services have been created to assist in the development of this sector, with significant advances in livestock research and development. Five research centres were established to meet the demands for new technologies, the Animal Improvement Institute, the Animal Products and Animal Nutrition Institute, the Range and Forage Institute, the Onderstepoort Veterinary Institute and the Onderstepoort Institute for Exotic Diseases. The activities of the first three of these have the predominant effect of improving livestock productivity while the latter two have the predominant effect of preventing productivity decline.

The Animal Improvement Institute is comprised of a number of livestock improvement schemes and for cattle these included the National Beef Cattle Performance and Progeny Testing Scheme and the National Dairy Cattle Performance and Progeny Testing Scheme. The objective of these schemes is primarily to develop technologies in order to improve livestock productivity. However, the value of livestock research in general has been estimated as being very low. First estimates by Van Zyl (1996) suggest that the rate of return (ROR) to livestock research is about 5% which is much lower than the estimated rate of return to public sector research of 44%, with benefits concentrated in the field crop and horticulture sub-sectors (Khatri *et al*, 1996). This article reports on a study which expanded the previous work by determining the rate of return at a more disaggregated level, with the focus on cattle research investments in the National Beef and Dairy Cattle Performance and Progeny Testing Schemes.

As a result of the dualistic nature of policy and support services in South African agriculture it is not surprising that small-scale livestock farmers were not members of the cattle improvement schemes in the past when the schemes were administered by the Department of Agriculture. These schemes were only confined to large-scale livestock commercial farmers. The small farmers did not have access to the production technologies developed by the schemes mainly due to the expensive nature of the technology promoted under the schemes. However, the taking over of the administration of these schemes by the Agricultural Research Council in 1995 made it possible to include small livestock farmers, but only a small proportion from the former homeland areas. This is because most of the small livestock farmers in these areas farm on communal land, i.e. their livestock depends on communal grazing and it is difficult for them to manage their herd properly. For example, when one farmer's performance tested bull is in the communal grazing areas, it will not only fertilises his or her cows or heifers only, but also other cattle of other farmers who are not members of the scheme.

The available data in the records and reports of the animal improvement schemes is mainly for large-scale commercial farmers because historically they were the only beneficiaries of the animal improvement research. This explains why the animal improvement schemes do not capture or have any information regarding the small-scale farmers. As a result, the small-scale livestock farmers were excluded from the analysis in this study.

The next section describes the objectives and developments of the cattle improvement schemes after which the returns to investments in these activities are estimated. Section three describes the methodology used in the analysis. The data, estimation process and results are reported in section four and the final section presents the conclusions, recommendations and limitations of the study.

2. THE CATTLE IMPROVEMENT SCHEMES IN SOUTH AFRICA

The Agricultural Research Council's Animal Improvements Institute is responsible for the two cattle improvement schemes, the National Dairy Cattle Performance and Progeny Testing Scheme and the National Beef Cattle Performance and Progeny Testing Scheme. This section will provide a brief description of the objectives and developments of these schemes before rates of returns to investments in these activities are estimated.

2.1 National dairy cattle performance and progeny testing scheme

The basic objective of this Scheme is to promote the economically and biologically efficient production of milk. The sub-objectives of this scheme are as follows: (1) to identify the shortcomings of herd management and to rectify them through technical advice; (2) to identify and cull the poor and inefficient producers; and (3) to evaluate the breeding potential of stud and Artificial Insemination (AI) bulls. By means of performance measurements the breeding value of individual cattle can be calculated and effectively applied to increase the genetic potential of the dairy cattle population.

The scheme was initially introduced in 1917 by the Friesland Cattle Breeders' Association of South Africa. In 1919, the State took full responsibility for the scheme, because it was in a better position to provide the finances and technical staff to ensure that all dairymen had access to the scheme. From 1919 to 1953 the scheme was administered by the Division of Dairying of the Department of Agriculture and Forestry and from 1953 it was transferred to the Animal Husbandry and Dairying Science Division of the Department of Agriculture which later became the Animal and Dairy Science Research Institute (ADSRI). The growth of milk recording in South Africa improved significantly with the introduction of owner-sampling. The number of participants doubled and the cows tested increased from 69 633 in 1980 to 137 632 in 1996. More than 29% of the national dairy herd is presently recorded and their performance per lactation is 50% higher than that of dairy cattle which are not in the scheme.

2.2 National beef cattle performance and progeny testing scheme

The objective of this scheme is to supply the beef industry with objective performance information to improve the biological and economical efficiency of beef production, through genetic improvement and improved management practices. Economically important traits such as reproduction rate, ease of calving, weaning weight, growth rate, feed conversion efficiency and various carcass traits receive attention.

The original Beef Cattle Performance and Progeny Testing Scheme was officially approved in December 1959, following a 2-year experimental period and has subsequently developed into a technically improved, popular and well-organised programme. The scheme, with its various phases, was supervised by an Advisory Committee, which consists of representatives from the various sectors of the beef cattle industry, namely: the Meat Board, South African Agricultural Union, Stud Book and Regional Performance Testing Committees. The technical guidance provided by this committee has made an important contribution to the development of the scheme. Commencing in 1960 with 30 members, the scheme expanded and since 1985 the membership stabilised and even dropped slightly due to changes in the structure of the scheme where payment for certain services became necessary (See Table 1). The number of bulls tested since 1963 increased as centres were established and expanded as shown in Table 1.

Table 1: Membership of the Beef Cattle Performance and Progeny Testing Scheme and number of bulls tested since 1960

Year	Members	Number of bulls tested
1960	30	-
1963	-	90
1970	50	615
1980	1 242	1 008
1990	1 798	1 450
1996	1 436	1 597

Source: Department of Agriculture (1979-1991) & ARC-Animal Improvement Institute (1992-1996)

2. MEASURING THE BENEFITS OF RESEARCH

Several methods have been used to estimate the returns to research investments, which usually require the estimation of the supply or production functions as initiated by Griliches (1958). Akino & Hayami (1975) have extended this method and while still using supply and demand elasticities they give more attention to the rate of technology adoption. The model directly measures the gains from research relative to the pre-innovation market equilibrium emphasizing the cost reducing nature of innovations. The movement of the supply function caused by the innovation is shown in Figure 1 with an increase in quantity supplied resulting in a decline in price. A constant elasticity of demand and supply are assumed and the supply shift due to technological change is considered to be pivotal divergent (see Figure 1). In this approach, social returns to research are measured as the changes in consumer and producer surpluses resulting from a shift in the market supply curve (Mohamed *et al*, 1995 Anandajayasekeram *et al*, 1996 and Kupfuma, 1993).

Lines dd and OS_o represent the actual market demand and supply curves, whereas S_n represents the supply curve that would have existed if the improved technologies (i.e. cattle improvement schemes in the case of this current study) were not developed. Assuming market equilibrium and no imports of cattle products (milk and beef), the shift in the supply curve from S_n to S_o would increase consumers' surplus by area ABC plus area BP_nP_oC; the producers' surplus by area ACO minus area BP_nP_oC; and social benefit by area ABC plus area ACO.

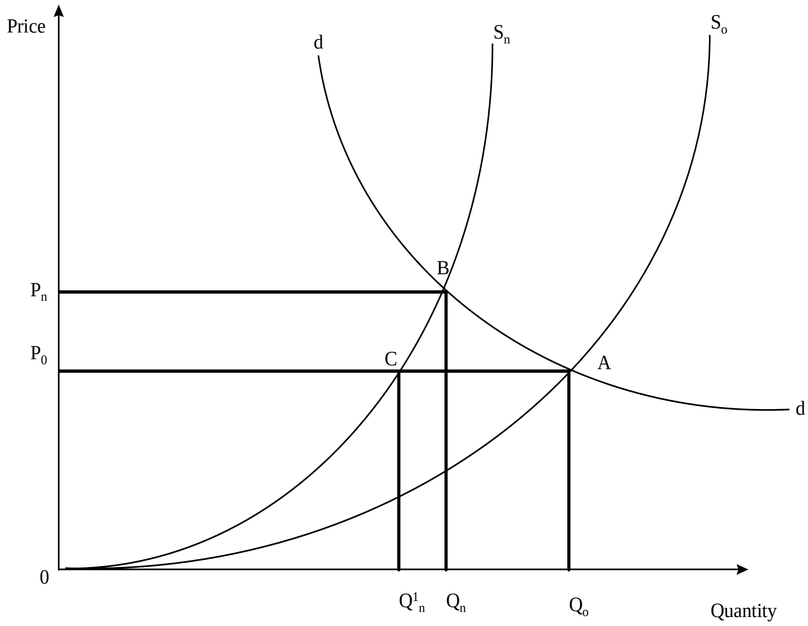

Figure 1: Akino – Hayami approach

The Akino-Hayami approach assumes a constant elasticity of demand and supply. These functions can be expressed as:

Demand function: $q = Hp^{-\eta}$

Supply function: $q = Gp^{\gamma}$

where q and p are quantity and price of cattle products respectively, η is the price elasticity of demand and γ is the price elasticity of cattle product supply. H and G are coefficients to be estimated. In the absence of improved technologies, a hypothetical supply function can be presented as

$$q = (1-h)Gp^{\gamma}$$

h represents the rate of shift in the supply function due to technological improvement. In competitive equilibrium, the supply function is equivalent to the marginal cost function derived from the production function. The relation between the rate of shift in the marginal cost function (h) and the rate of shift in the production function (k) can be approximated as $h \approx (1+\gamma)k$. Given these definitions, Akino & Hayami (1975) define the areas in Figure 1 as:

$$area\ \text{ABC} \approx 0.5 p_o q_o \frac{[k(1+\gamma)]^2}{\gamma+\eta} \quad ; \qquad area\ \text{AOC} \approx k p_0 q_0$$

$$\text{area } BP_nP_oC \approx \frac{p_0q_ok(1+\gamma)}{\gamma+\eta} * [1 - \frac{0.5k(1+\gamma)\eta}{\gamma+\eta} - 0.5k(1+\gamma)] \; ; \quad \text{area } ACQ'_nQ_o \approx (1+\gamma)kp_0q_0$$

This approach was used to estimate the returns to investments in cattle improvement schemes in South Africa.

4. DATA, ESTIMATION AND RESULTS

The data used in this study are from the Abstract of Agricultural Statistics, Government budgets, the Central Statistical Services (CSS) and Annual Records of the Livestock Improvement Schemes from Agricultural Research Council-Animal Improvement Institute (ARC-AII). The price elasticity of demand and supply (η and γ) were obtained from previous studies. The long run demand elasticities of fresh milk and beef are –0.51 (Mckenzie & Nieuwoudt, 1985) and -0.96 respectively (Hancock *et al*, 1984). The estimated long run supply elasticity of livestock output is 0.32 (Townsend, 1998). The rate of shift in the aggregate cattle production function (k) is derived by estimating the yield differences between those cattle in the scheme and those not in the scheme. Fresh milk production data for the dairy scheme cattle have been recorded annually as well as the yield advantage percentages, ranging from 50% to 58% (Department of Agriculture, 1979-1994; ARC-AII, 1995,1996). National beef production averages derived from the *Abstract of Agricultural Statistics* (Department of Agriculture, various years) were used for the beef scheme, and the study assumed that the yield of performance tested beef cattle is 50% above the national average, thus a 50% yield advantage, as in dairy, was assumed. This assumption was made and agreed upon after some discussions with the senior staff members of the Agricultural Research Council – Animal Improvement Institute (ARC-AII), who are in charge of the schemes. Due to the unavailability of readily available data regarding the yield advantages of other animal improvement schemes including beef scheme, the key informants agreed and indicated that the yield advantages for all other schemes, although not recorded, are similar to those of the dairy scheme. The reason why this information is not readily available is because ARC-AII is not responsible for slaughtering, but only monitors the performance tested animals and when they have reached the required body mass, they are then sold to the abattoirs for slaughtering. However, the institute do milk the performance tested dairy cows and record this information, then sell the milk to private companies for processing. That's why the yield advantages of the dairy scheme are readily available.

This study assumes that farmers have adopted a complete package of innovations (breeding technologies, feeding technologies, etc) introduced in the schemes and the adoption path is linear. Since the study has assumed 1970 as the initial year for all the improvement schemes as well as a lead period of ten years, the adoption rates were calculated from 1980 (i.e. the initial year of adoption). The rates of adoption were estimated as the percentage of animals under the improvement scheme relative to the total number of animals registered in the South African Studbook. The adoption ceiling was taken to occur after 6 years from the initial year of adoption thereafter declining to zero after a further 5 years. The assumptions were also made after getting opinions of key informants, i.e. ARC-AII staff member, who know the operations of these schemes better and were then agreed upon. The technological adoption ceilings (at the peak year) for the dairy and beef cattle schemes were estimated as 40.1% and 11.6% respectively. The study used real producer prices of fresh milk and beef that were calculated from data obtained from the *Abstract of Agricultural Statistics* (various years). The Research and Development expenditures over the period 1970–1979 were also estimated and deflated to 1996 real values. The annual total research benefits to the cattle improvement schemes were estimated by adding areas ABC and AOC on an annual basis.

Estimates of the gross benefits and the R&D costs, allow the estimation of the payoff to the investment in cattle production research. The incremental net benefit can then be derived by subtracting the research and development costs from the gross benefits. The net present values (NPVs) for all the cattle improvement schemes were then calculated at three levels of the real discount rate, i.e. 5%, 10% and 15%. Equating the NPV to zero gives the internal rate of return (IRR). The estimated IRRs and NPVs at 5, 10 and 15 percent are shown in Table 2. This table reveals that during 1970 to 1996 investments in the dairy and beef cattle improvement schemes generated rates of returns of about 51% and 44% respectively. In a nut-shell, for every one rand invested in these schemes generated annual profits of 51 and 44 cents respectively (Gittinger, 1982). These RORs are greater than the aggregate rate of return to animal improvement schemes, which is about 18-22%. This suggests that the performance of these cattle schemes may have exceeded the performance of some of the other animal improvement schemes, namely pig, poultry and small stock schemes.

The difference between the estimated aggregate and disaggregate returns could be the result of the different methodologies used for these estimations. While the aggregate return was estimated using the production function approach where total livestock output including poultry was used, the disaggregate returns were estimated using Akino-Hayami approach where individual livestock product output was used, i.e. fresh milk output in the case of dairy scheme and beef output in the case of beef scheme. During the past 27 years, using 5 percent discount rate, investments in the dairy and beef cattle schemes generated a NPV of R3305 million and R1 934.9 million respectively. In other words, the annual net present values for these schemes are about R122.4 million and R71.7 million respectively. When the discount rate was changed to 10% and 15% the NPVs for all the schemes are still substantial and positive.

Table 2: Returns to Investments in Animal Improvement Schemes: 1970–1996

Activity	Measure of Return			
	IRR (%)	**NPV at 5% (R million)**	**NPV at 10% (R million)**	**NPV at 15% (R million)**
Aggregate Results (Total Output Approach)				
Aggregate Animal Improvement Scheme[1]	18-22	None	None	None
Disaggregate Results (Akino-Hayami Approach)				
Dairy Cattle Improvement Scheme	51	3305.0	1428.2	652.8
Beef Cattle Improvement Scheme	44	1934.9	819.1	364.9
Sensitivity Analysis on Disaggregate Results (Simple Benefit-Cost Analysis Approach)				
Dairy Cattle Improvement Scheme	51	2573.8	1102.9	507.9
Beef Cattle Improvement Scheme	29	774.9	267.5	98.3

1 The aggregate return to animal improvement scheme was estimated by Townsend (1998) using the supply response model, i.e. the production function approach. The total livestock output including poultry was regressed to real prices of livestock, dips and maize, weather and livestock research and development (R&D) expenditures. A second degree polynomial lag structure was used to estimate the elasticity of R&D expenditures lagged for 20 years, which was then used to calculate the aggregate return to animal improvement scheme.

A simple benefit-cost model was used to analyze the robustness of these return estimates. In contrast to the Akino-Hayami model, the benefit-cost model assumes a perfectly inelastic supply and a perfectly elastic demand curve and thus output prices do not change with changes in the supply curve. In addition the model does not require the information of price elasticities of demand and supply when estimating the benefits. The gross benefits were estimated by multiplying the yield gain due to technological change by the constant price. Similar research and development expenditures as well as lead period, as in the Akino-Hayami model, were used when estimating the incremental net benefits. The results from this analysis are also presented in Table 2. The results indicate that the rate of return to the dairy improvement scheme is the same as that estimated by Akino-Hayami model, but the NPVs are lower at all discount rates. The rates of return as well as the net present values of the beef cattle improvement scheme are significantly lower than those estimated by the Akino-Hayami model, thus indicating a larger variation of the assumptions made. That is, the larger the variation of the assumptions between the Akino-Hayami and Benefit-Cost models, the larger the difference between the estimated rates of returns.

5. CONCLUSIONS, RECOMMENDATIONS AND LIMITATIONS OF THE STUDY

The rates of returns to the dairy and beef cattle improvement schemes were estimated to be 51% and 29% to 44% respectively. These RORs are higher than the ROR derived for aggregate livestock research suggesting that the performance of these schemes may have exceeded performance of some of the other animal improvement schemes and are indeed comparable to returns from research on other agricultural sectors. These schemes have been primarily dependent on public funding and in the climate in increased competition for government resources, alternative cost recovery approaches need to be pursued. The private sector should provide the majority of the funding and the high estimated returns should be sufficient enough to attract private investment (whether from farmers or industry). The potential for recovery by the private sector seems apparent by the high returns derived from these cattle improvement research investments. The adoption of the technology developed by these cattle schemes remains confined to large scale commercial producers and the continuing challenge is to develop appropriate technology suitable for the wider South African clientele.

This study has several limitations that should be considered when interpreting the results and the recommendations thereof. The limitations are related to the availability and quality of data used since the livestock improvement R&D programs were designed without due consideration for the need to collect information to be used for impact assessment. The other major limitations of the study are listed below:

- The annual R&D expenditures collected from various records were not consistent in nominal terms. As a result the derived inconsistent nominal R&D series was used to estimate an R&D index.

- The yield levels of "with" and "without" livestock improvement schemes, which are an important component in the calculation of benefits, had to be estimated for beef scheme except that of the dairy scheme. Given the absence of baseline data, the process was extremely difficult. The opinions of key informants were used during the estimation process.
- The absence of appropriate data made it impossible to adequately assess the impact of livestock improvement R&D on the environment, gender, employment and food security. As a result, the benefits and costs may have been underestimated or overestimated.

- The study assumed a similar shape and length of adoption (11 years) for all the animal improvement schemes. The adoption rates were linearised according to the assumed length period of 11 years when the adoption was increasing to reach the ceiling and declined to zero during the following 6 years.

NOTE:

1. *The authors wish to thank the staff members from the Agricultural Research Council-Animal Improvement Institute and the Unit for Development Impact Analysis for their helpful discussion and comments. Constructive comments received from two ananymous referees are also acknowledged with thanks.*

REFERENCES

AKINO, M. & HAYAMI, Y. (1975**).** Efficiency and Equity in Public Research: Rice Breeding in Japan's Economic Development. *American Journal of Agricultural Economics,* 57:1-10.

ANANDAJAYASEKERAM, P.; MARTELLA, D.R. & RUKUNI, M. (1996). *A training manual on research and development evaluation and impact assessment of investments in agricultural and natural resources research*. SACCAR, Gaborone, Botswana.

ARC-ANIMAL IMPROVEMENT INSTITUTE (1992-1996). *Annual and technical reports of the livestock improvement schemes*. Irene, South Africa.

DEPARTMENT OF AGRICULTURE (1979-1991). *Biennial reports of the Animal and Dairy Science Research Institute.* Irene, South Africa.

GITTINGER, J.P. (1982). *The economic analysis of agricultural projects*. John Hopkins University Press. Baltimore, Maryland.

GRILICHES, Z. (1958). Research costs and social returns : Hybrid corn and related innovations. *Journal of Political Economy*, 66:419-431.

HANCOCK, P.J., NIEUWOUDT, W.L. & LYNE, M.C. (1984). Demand analysis of meat in South Africa. *Agrekon*, 23(2):26-29

KHATRI, Y., THIRTLE, C. & VAN ZYL, J. (1996). Public research and development as a source of productivity change in South African agriculture. *South African Journal of Science,* 92:143-151.

KUPFUMA, B. (1993). *The payoffs to hybrid maize research and extension in Zimbabwe : An economic and institutional analysis.* Unpublished MS Thesis. Machigan State University. East Lansing, United State of America.

MCKENZIE, C.C. & NIEUWOUDT, W.L. (1985). Estimation of demand and supply functions for fresh and industrial milk in South Africa. *Agrekon,* 24(2):27-33.

MOHAMED, M.A., MASTERS, W.A. & SANDERS, J.H. (1995). Returns from research in economies with policy distortions : Hybrid sorghum in Sudan. *Agricultural Economics,* 12:183-192.

MUDHARA, M., ANANDAJASERAM, P., KUPFUMA, B. & MAZHANGARA, E. (1995). *Impact assessment of cotton research and the enabling environment in Zimbabwe, 1970-1995*. SACCAR, SADC.

NKOSI, S.A. & KIRSTEN, J.F. (1993). The marketing of livestock in South Africa's developing areas : A case study of the role of speculators, auctioneers, butchers and private buyers in Lebowa. *Agrekon*, 32(4):230-237.

STEYN, G.J. & D.R. TAPSON (1992). Farming Systems Research and Extension (FSR/E) Approach in Third World Livestock Development. In: Nkosi, S.A. (1994). *Livestock Marketing in South Africa's Developing Areas : A Case Study in Lebowa*. Unpublished M.INST.AGRAR Thesis. University of Pretoria. Pretoria, South Africa.

TOWNSEND, R.F. (1998). *Returns to livestock research in Southern African agriculture : A re-examination.* Agricultural Research Council, Pretoria, South Africa.

VAN ZYL, J. (1996). *Returns to research on crops, horticulture and livestock in South Africa*. Agricultural Research Council mimeo.