

ESTIMATING TECHNOLOGY'S CONTRIBUTION TO PRODUCTIVITY IN THE ZIMBABWEAN SUGAR INDUSTRY

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Abstract

A Cobb-Douglas production function was used to estimate the contribution to productivity (yield per hectare) of technology (ZSA Experiment Station expenditure), water (irrigation plus rainfall), production cost index, export price of sugar and area harvested, during the 27-year period of 1970-1996. With a lag of four years, technology's contribution was found to be 42%. Of the 42%, research was estimated to have contributed 64% and technology transfer 36%, with the latter declining from 62 to 19% over the period. The decline in the industry's yield per hectare over the period has resulted in an overall negative technology B:C ratio. However, the value of defensive research (against yield decline) is estimated empirically as 19% of the industry's total value with a B:C ratio of 2:5.

Introduction

Although commercial irrigation of sugarcane in the south eastern lowveld of Zimbabwe began in 1928, production on a large scale could only start in 1960 with the completion of the Mutirikwi dam. From that time the expansion of the industry, led by Triangle Ltd and Hippo Valley Estates, was rapid and today consists of 45 000 fully irrigated hectares producing five million tons of cane per annum and directly employing more than 20 000 people (Musikavanhu, 1998).

To the credit of those responsible for the early development of the industry, the importance of having technological back-up available locally was realised from the beginning. In 1965 the then Rhodesia Sugar Association employed the Director of the South African Sugar Association Experiment Station (SASEX), Mr J Wilson, to advise on the burgeoning industry's organisational requirements for research and specialist services. The consultant's report (Wilson, 1965) recommended the establishment of *its own* 'Field Station and Field Service Laboratory' to conduct (i) field trials on water and fertiliser requirements, (ii) variety trials and seed multiplication, (iii) soil and plant tissue analyses for advisory purposes, (iv) recording of meteorological data for irrigation control, and (v) to provide a headquarters for a Field Inspection Service. Three points of particular interest emerge from the Wilson report:

- Firstly, the recommendation that Zimbabwe should follow the South African example of operating its own field station rather than expect the Government to supply its technological requirements as it did for all other crop com-

modities (except tobacco) at that time. In fact, Government had suggested a form of partnership in the operation of its Chiredzi Research Station which had just been established in the area. The high quality and quantity of the work done at the Zimbabwe Sugar Association Experiment Station (ZSAES) since that time, can be attributed very largely to the decision to be independent of Government.

- Secondly, the Wilson report implied that since "...there are no major factors limiting crop production at the present time and there are no major problems requiring urgent investigation", research *per se* was not necessary. The emphasis of the report was on the provision of technical services such as soil and leaf analysis, and the testing of 'imported' technologies, such as varieties and fertiliser and irrigation regimes, under local conditions. At that time, Wilson believed that, "...other problems are largely speculative and although 'forewarned is forearmed' it would be unwise to over exaggerate their importance and to embark upon nebulous research projects of doubtful outcome." The de-emphasis of research in the Wilson report was acceptable at the time because the services and research results – particularly varieties – of the SASEX were freely available to the fledgling industry. Furthermore, it made it financially possible for the Sugar Association to establish immediately its own independent Experiment Station and avoid dependence on Government research facilities and services in the area. Research in the sense of developing new technologies can, however, be considered to have started in 1976 (Zhou, 1996), ten years after the founding of the ZSAES, with the initiation of a cane breeding programme.
- Thirdly, the Wilson report did not include extension among the recommended functions of the Field Station. However, he felt that, "Certain routine advisory services should be made available to all growers of sugarcane in order to maintain at uniform level the present high standards of management and irrigation control." Consequentially the transfer of technology was generally limited to the providing of advice on request and usually, although not exclusively, on the ZSAES. Following recommendations in a report on the services required to meet proposed new developments in the Zimbabwean sugar industry (Donovan, 1994), the ZSAES adopted a Mission Statement which for the first time included research and extension in its functions.

Sources of technology

Three successive sources of technology, *craft skills*, that is, growers' own innate abilities; *imported technology*, knowledge, experience and material brought in from other environments; and *local technology* generated by research conducted locally, have been proposed for sugarcane production in South Africa (Donovan, 1992).

In the case of the Zimbabwean sugar industry the production of sugarcane between 1928 and 1960 may have depended to some extent on the craft skill of the sugar pioneers, Tom MacDougall and others, although they did use mainly South African technology. From 1960 to the present time the technologies used for cane production in the Zimbabwean sugar industry, have been almost exclusively imported from South Africa and Mauritius.

The third source, local technology, is only likely to start making a contribution to productivity when two locally selected cane varieties, ZN1L and ZN2E (Anon, 1994-95) are in a few years grown on a commercial scale.

The previous studies on the sources of technology on sugar (Donovan, 1992), tea (Donovan and Limwado, 1995a) and tobacco (Donovan and Cousins, 1995) have all shown that, for various reasons, productivity (yield per hectare) declines after a few years during the imported technology phase. Figure 1 indicates the same applies in the Zimbabwe sugar industry.

Technology evaluation

Research to generate technology is a scientific activity but, because it has a cost and makes a return by contributing to productivity, it is also an economic activity capable of economic analysis (Schultz, 1953). For example, a new technology such as a sugarcane variety, produced by research, is simply one of the inputs in the cane production process and

should therefore be included among the costs of production, while its return can be evaluated in terms of the increase in productivity for which it has been specifically responsible.

Calculating the cost of research is a matter of arithmetic, albeit often made tedious by obscure accounting methods, but which can be facilitated when accounts are structured in terms of mission functions (such as plant breeding, entomology and agronomy) and not in terms of its resources and operational functions (such as staff, transport and chemicals). However, estimating the returns on research is more difficult.

Most studies of returns on research have used surrogate indicators of change in output and use the economic surplus method to express returns in terms of the *social benefit* derived from the expenditure of public funds. This may be appropriate when, as in most countries, agricultural research is funded by the State out of the public purse and when the results are required for broad national economic policy decision-making. However, this method has limitations when used to evaluate commodity research funded privately, mainly because neither the separate research and extension effects nor the separate consumer (social) and producer (profit) benefits can be differentiated.

Unfortunately there have been few studies on the costs and returns on research conducted by non-government institutions when the results are required to determine the cost effectiveness of research for a particular commodity, funded by producers. In southern Africa, the first of these studies was probably the research conducted on the South African sugar industry (Donovan and Nieuwoudt, 1992). Using similar methods, this was followed by estimates of the returns on research in the Malawi tea industry, and in the previously referred to Zimbabwean tobacco industry, while this study is a first attempt at estimating the value of the technological output of the ZSAES.

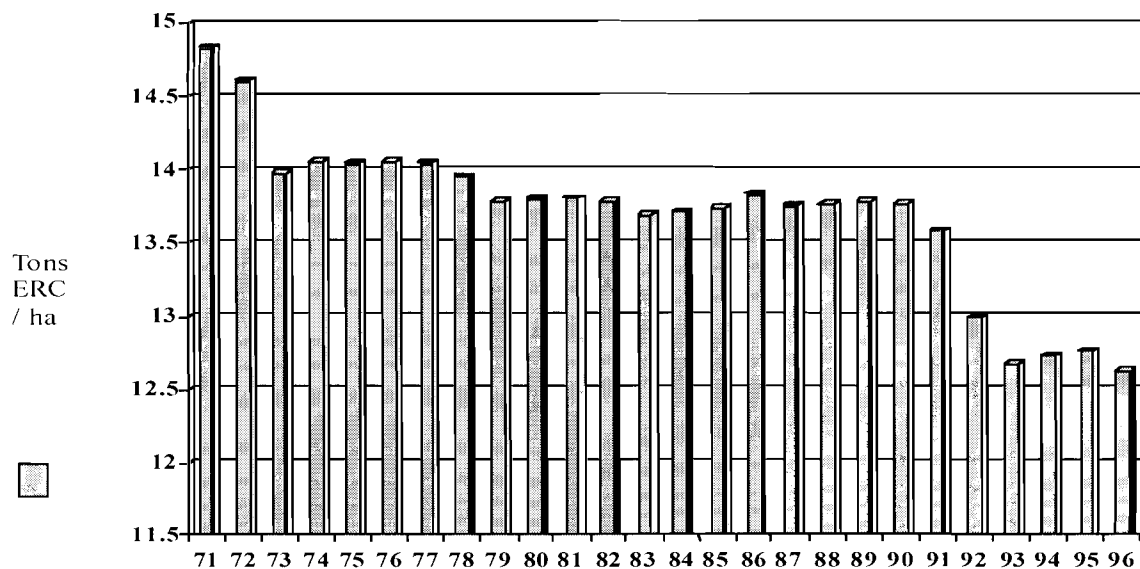


Figure 1. Progressive average yields, tones ERC per hectare, 1971-1997.

Methodology and data

The method used is to include those factors known or considered to contribute significantly to productivity (yield per hectare), including technology, in a Cobb-Douglas type production function to measure (in terms of their coefficients) their respective contributions to productivity. This method of estimating a factor share is theoretically only justified under conditions of constant returns, but its use to generate purely comparative information for practical policy and management purposes is considered acceptable. The Cobb-Douglas production function equation used was:

$$\log Y = K + \log X_1 + \log X_2 + \log X_3 + \log X_4 + \log X_5$$

where Y = yield (of ERC*) per hectare of the Zimbabwe sugar industry, and with the following factors considered to contribute to productivity:

X_1 = technology (expenditure at ZSA), Z\$/ha, 1996 = 100

X_2 = water, irrigation + rainfall, mm

X_3 = production cost index, 1996 = 100

X_4 = shadow (export) price of sugar, Z\$/ton, 1996 = 100

X_5 = area harvested, hectares.

*Yield in Zimbabwe is expressed as ERC (estimated recoverable crystal).

The effect of *technology lag* was estimated by repeating the analysis with the technology factor retarded for as many years as possible. Estimating the lag effect was limited because the ZSAES was established only five years before the data for the other factors were available. Furthermore, expenditure at the ZSAES (proxy for technology) for the retarded years had to be estimated because the actual data were not available. Although the analysis with a four-year technological lag appeared to have the best fit, this result must be regarded as tentative.

Sufficiently detailed and collated data on all factors required for the production function analyses were available only from 1970 onwards (Appendix 1). The time series is therefore limited to 27 years, which places limitations on the interpretation of some of the results. Unless specifically referenced, the cane production data for 1970 to 1990 were obtained from a ZSAES report (Cackett, 1990). Production data for 1991 to 1996, as well as the rainfall and expenditure data were obtained from the ZSAES Director (¹personal

communication). The irrigation, sugar price and production costs index data were supplied by Triangle Ltd and Hippo Valley Estates. The series of production function analyses, including those to determine research lag, were conducted by the Biometry Department of SASEX (²personal communication).

Results*Evaluation of technology*

Despite the tentative nature of a four-year technology lag, it was decided to use the results of the analysis in which technology was lagged four years in all subsequent discussions and conclusions. Furthermore, analyses in which the extremely abnormal rainfall years of 1992 and 1993 were omitted gave more satisfactory results than the analyses with 27 years of data; consequently all analyses used also excluded the data for those two years.

Musikavanhu (1998) states that, "Rainfall distribution during the peak growth period (December to February) is the most critical determinant of yield." Analyses were, therefore, carried out to compare the results with X_2 , the 'water' factor, comprised of (a) total rainfall + irrigation, or (b) Dec-Feb rainfall + irrigation, or (c) Dec-Feb rainfall only. There was very little difference between these three 'water' regimes in their effect on the results of the analyses, although (b) had the best fit and (c) the poorest fit. This may support Musikavanhu's contention that the December to February rainfall has the greatest effect on yield but not necessarily that it is its most critical determinant of productivity. Subsequent discussion and conclusions are, therefore, based on the results of the analyses in which Dec-Feb rainfall + irrigation data were used for the X_2 factor.

In all analyses the X_2 (water factor), X_3 (index of production costs) and X_4 (shadow price) made the least contribution to the fit and an analysis was thus carried out using only the X_1 (technology) and X_5 (area harvested) factors. However, this analysis resulted in little difference in the magnitude of the coefficient for the technology factor, as can be seen in Table 1.

¹ Dr M Clowes, Director, Zimbabwe Sugar Association Experiment Station.

² Mr MG Murdoch, Head, Biometry Department, SASEX.

Table 1. Coefficients of the technology factor (X_1) lagged four years, for three different water factors (X_2), [1] irrigation + total rainfall, [2] irrigation + Dec-Feb rainfall, [3] Dec-Feb rainfall only, and [4] irrigation + total rainfall with the independent variables (X_3), (X_4) and (X_5) omitted. (Coefficients of the other independent variable included for comparison).

Independent variables	Water regimes			
	Irrigation + total rainfall	Irrigation + Dec-Feb rainfall	Dec-Feb rainfall only	Irrigation + total rainfall
Technology (X_1)	0,4009	0,4357	0,4330	0,4059
Water (X_2)	0,1623	0,1435	0,0295	-
Prod. costs (X_3)	0,1682	0,1481	0,2180	-
Price (X_4)	-0,0161	0,0402	-0,0103	-
Cane area (X_5)	0,4280	0,4127	0,4550	-
Adj R ²	0,55	0,61	0,47	0,48
SE	0,035	0,033	0,038	0,032

In terms of the hypothesis of Donovan and Nieuwoudt (1992), the contribution of technology to the industry's increase in productivity (in tons ERC per hectare) can be calculated as the product of the increase in ERC yield per hectare and the coefficient of the technology factor in the equation, viz 42%. In the previous studies of this kind referred to, increase in yield per hectare was determined as the difference between the yield at the beginning and at the end of the series. However, in this case, industrial yields per hectare were lower at the end of the series than at the beginning, so yield increase was determined as the sum of the individual annual yields that exceeded the progressive average, as shown in Figure 2.

Table 2 sets out the process for calculating the value of technology, by quintades (five-year periods), in the Zimbabwean sugar industry from 1970 to 1996.

The technology factor represents the total output of all ZSAES functions, viz. research, technology transfer and technical services. In order to assess the value and cost effective-

ness of the ZSAES's work, and to obtain some quantitative data on which policy and management decisions can be based, it would be advantageous to estimate the shares of these three components of the ZSAES's technology output.

Evaluation of research and technology transfer

In a study of the returns on extension in the South African sugar industry, Donovan and Darroch (1991) used the hypothesis that, "The estimated change in the relationship between the industrial yield and the technological yield (obtained by technologists in field trials), can be used as a measure of the transfer of technology." Figure 3 shows and Table 3 measures changes in the relationship between industrial and technological yield in the Zimbabwean sugar industry between 1970 and 1989. The comparison was limited to that 20-year period because drought affected differentially the industrial and technological yields in the 1990s.

To measure the changes in the relationship between industrial and technological yields over time it is necessary to use a

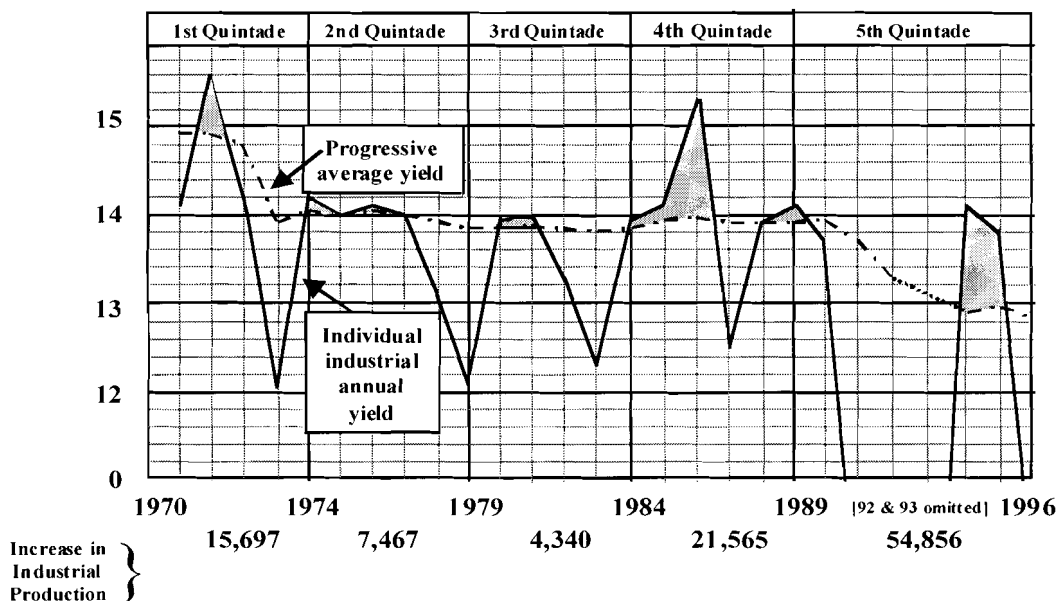


Figure 2. Shown shaded, increases of individual industrial annual yields over progressive average industrial yield, tons ERC per hectare, 1970-1996, [increases in industrial production = increases in yield per hectare x area harvested].

Table 2. Evaluation of technology by quintades, Z\$m, 1970-1996.

	[1]	[2]	[3]	
	Increase of industrial yield over mean ERC/ha	Increase of industrial production (tons ERC)	Value of increased industrial production (Z\$m)	Value attributable to technology (Z\$m)
	[see Figure 2]	[1] x hectares	[2] x price	[3] x 42%
1st quintade	1,00	15,697	33,50	14,07
2nd quintade	0,42	7,467	32,82	13,78
3rd quintade	0,19	4,340	11,66	4,90
4th quintade	0,83	21,565	50,93	21,39
5th quintade	2,05	54,856	130,73	54,91
Total			259,64	109,05

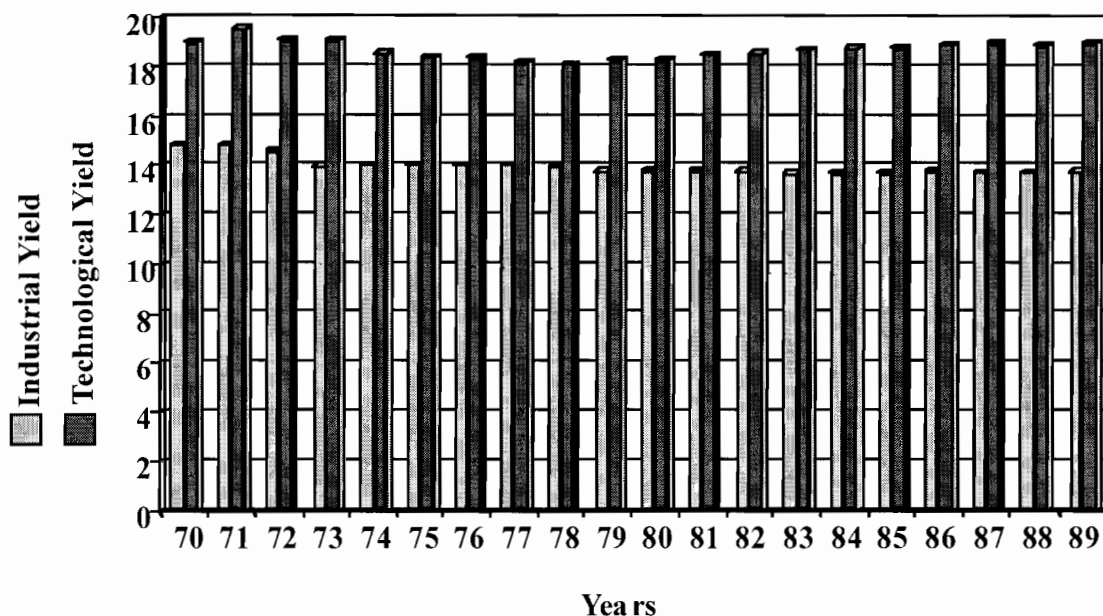


Figure 3. Technological and industrial progressive average yields compared, tons ERC per hectare, 1970-1989.

Table 3: Changes in technological and industrial progressive average yields, tons ERC/ha, as percentages of climatic potential yield (CPY) of 25 tons ERC/ha, by quintades, 1970-1989.

	1st quintade 1970-74	2nd quintade 1975-79	3rd quintade 1980-84	4th quintade 1985-89
Technological yield:				
Initial	19,01	18,41	18,29	18,80
Final	18,53	18,13	18,77	18,95
Change	-0,48	-0,28	+0,48	+0,15
Change as % of CPY (T)	-1,92	-1,12	+1,92	+0,60
Industrial yield:				
Initial	14,83	14,05	13,80	13,73
Final	14,06	13,78	13,71	13,78
Change	-0,77	-0,27	-0,11	+0,05
Change as % of CPY (I)	-3,08	-1,08	-0,44	+0,20
Ratio of T:I	by quintades	38:62	51:49	81:19
	overall	61:39		

common base, and for this purpose the concept of a climatic potential yield (CPY) is appropriate (Donovan and Darroch, 1991). In the absence of a locally estimated CPY, 25 tons ERC per hectare is used. This is nearly twice the average industrial yield, and about 20% higher than the highest yield recorded for 1994 and 1995 (Anon, 1994-95).

The ratios of technological to industrial yields given in the last line of Table 3 indicate that technology generation (research) accounted for 61% and technology transfer accounted for 39% of the total value of technology during the 20-year period. The change in the ratios by quintades is of particular interest, indicating that the research contribution increased from 38% in the first quintade, through 51% and 81% for the second and third quintades, and then declined to 75% in the last quintade. Conversely, the contribution of technology transfer, that is, advisory and extension,

declined from 62% during the first quintade, through 49% and 19% during the second and third quintades, and then increased to 25% during the last quintade.

Evaluation of technical services

In most commodity research organisations, technical services, such as soil, leaf and water analyses, are provided on a user-pays basis with the charges based on marginal cost, that is, more or less on a non-profit basis. If no charges are raised for services or if their costs exceed the charges made for them, any estimates of the value of research and technology transfer will be under-estimates; furthermore, those not using the services will be subsidising those who do. Without detailed information on costs of technical services and the charges raised on them, it is not possible to determine the effect that undercharging for services has on the evaluation

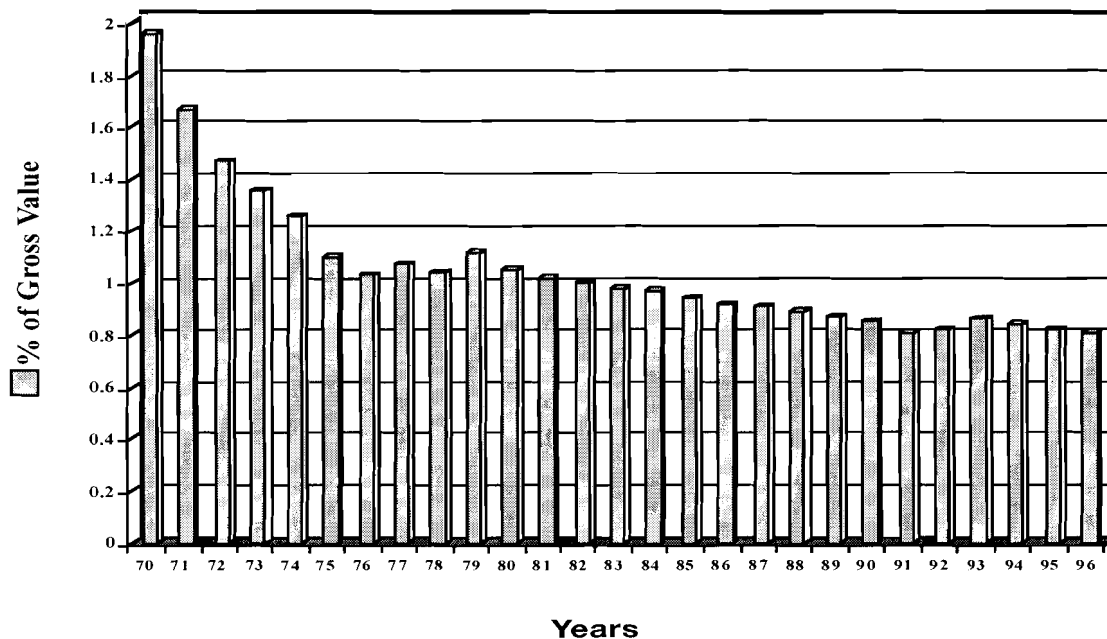


Figure 4. Progressive average cost of technology as a percentage of the gross value of the industry, 1970-1996.

Table 4. Comparison of expenditure on technology by commodity associations in southern Africa, expressed as a percentage of the commodities' gross value.

		Zimbabwe	Malawi	South Africa
Sugar	mean	1,05 ^{bd}	-	1,57 ^{ac}
	highest	1,96 ^{bd}	-	1,79 ^{ac}
	lowest	0,81 ^{bd}	-	1,55 ^{ac}
Tobacco	mean	1,10 ^{bc}	0,53 ^{bc}	-
	highest	1,37 ^{bc}	0,83 ^{bc}	-
	lowest	0,90 ^{bc}	0,29 ^{bc}	-
Tea	1988-89	1,10 ^b	1,20 ^b	0,50 ^b

^a = Research, Extension, Advisory and Services
^b = Research, Advisory and Services – no Extension
^c = 1980-89
^d = 1970-96
 Source: Donovan (1995)

of research and extension. However, it is believed that the effect would be relatively small in the case of the Zimbabwean sugar industry.

Costs of technology

The cost of technology is represented by expenditure on all functions of the ZSAES. For the period 1970-1996 this is given in the Technology column of Appendix 1, in Z\$ per hectare under cane adjusted for CPI (100 = 1996).

Before examining the benefit to cost aspects, it is instructive to express costs of technology as percentages of the gross value of the commodity. For the Zimbabwean sugar industry this is shown in Figure 4.

It is in these terms that comparison with other commodities can be made, for example in Table 4. The data used to calculate these percentages are not always of the same func-

tions or mix of functions; some are of research costs only, most include technical services and some advisory services; others include extension and training. The comparisons are therefore to be interpreted in general and broad terms.

Benefit:cost ratios

It is now possible to calculate the benefit:cost ratios for technology at the ZSAES. The 'benefit' is the value attributable to technology which was calculated in column (4) of Table 2 and the 'cost' is the total expenditure at the ZSAES (i.e. the product of columns 3 and 7 of Appendix 1). Table 5 sets out these ratios by quintades.

The negative ratios indicate that costs of technology generation exceed the returns in terms of increased industrial productivity. This is inevitable if no new productivity increasing technologies are generated by research. Furthermore, negative benefit:cost ratios are typical of dependence on import-

Table 5. Calculations of Benefit:Cost ratios, by quintades, for Zimbabwe Sugar Association Experiment Station, 1970-1996.

	Value attributable to technology (Z\$m) (from Table 2)	Cost of technology (Z\$m) (from Appendix 1)	Benefit:Cost ratios
1st quintade 1970-74	14,07	26,23	-1,86
2nd quintade 1975-79	13,78	24,73	-1,79
3rd quintade 1980-84	4,90	30,24	-6,17
4th quintade 1985-89	21,39	30,13	-1,41
5th quintade 1990-96	54,91	32,11	+1,71
Overall	109,05	143,44	-1,32

ed technology, which is still the situation in the Zimbabwean sugar industry.

Discussion

Interpretation of analyses

Despite the short time series of 27 years, which included two years of drought with consequent serious effects on production, the results of production function analyses were sufficiently consistent, accounted for enough of the variability and had acceptable levels of significance (as indicated in Table 1) to allow valid conclusions to be drawn. These analyses indicate that 'technology' and 'area harvested' are the only two factors strongly correlated with yield per hectare. The 'technology' result is to be expected because both yield per hectare and expenditure on technology declined throughout the period.

The strong correlation of 'area harvested' with yield per hectare is not consistent with previous studies but may be accounted for by the higher yields per hectare commonly obtained from plant cane and early ratoons, and probably because the new areas brought under cane production in the Lowveld are on more productive soils than the older areas. The 'water' and 'production cost' factors were positively correlated with yield per hectare but not strongly so. Because the excess of either of these inputs (for example over irrigation and excess nitrogen) can lead to the reduction of yield per hectare, this result can be expected. The 'price' factor appeared to have no effect on yield per hectare; this is consistent with other studies and is to be expected.

Interpretation of results

The two most important factors affecting the findings of the study are that, during the 27 years of the study (1970-1996), the yield per hectare of the industrial crop and the investment by the industry in technology have both declined (Figures 1 and 4). Under these circumstances it is not possible for technology produced by the ZSAES to make a positive contribu-

tion to productivity in the industry. Without the input of technologies developed specifically for the local environment, particularly locally bred varieties, that can raise the industry's yield per hectare, the decline is unlikely to be arrested.

Research's contribution to productivity

Fortunately the imported technologies used to establish the industry on a large scale, in the early 1960s, were already well developed (by research elsewhere) and happened to be well suited to the Lowveld environment. Particularly so is the use, from the beginning, of NCo376, which is a variety of high general adaptability and ratoonability. This meant that productivity started at a higher base level than would otherwise be expected when a crop is established in a new area with imported technologies.

However, the high original base level of productivity, which has fortuitously been so advantageous for the industry, reduces the rate of return that can be expected from locally generated technology. For example, if the recently released variety ZN11 increases industrial productivity by 0,63 tons ERC per hectare³ and is planted on as much as 5% of the total area under cane annually, it would take at least 20 years to raise productivity by only about 5%, i.e. from 13,0 to 13,65 tons ERC per hectare, on the total area under cane.

The equation, therefore, for estimating the return on technology needs to include not only the increase in productivity due to a new technology and the estimated cost of producing the new technology, but also the present level of productivity in the industry and particularly the rate of adoption of a new technology by the industry.

The contribution of technology transfer (extension) to productivity

The importance of this factor, and especially the rate of

³ ZN11 outyields NCo376 by 0,9 tons ERC/ha (all year) in ZSAES trials (see Table 1), but industrial yields are approximately 70% of technological yields, i.e. 6,3 tons ERC/ha.

adoption of technology, is through extension action, resources devoted to it and to some extent on the structure of the industry. For example, in the South African sugar industry which has about 150 commercial growers per Extension Officer, a grower to miller ratio of 100 to 1 and 80% of the cane produced by growers, 60% of the value of technology over the period 1925-1985 was found attributable to extension (Donovan and Darroch, 1991). On the other hand, the Zimbabwean industry with no dedicated extension staff, a grower to miller ratio of only 30 to 1 and with growers producing only 21% of the total, the structure and policies are very different. Under these circumstances, and taking into account the finding in this study that the technology transfer share of the total technological contribution to productivity has declined from 62% in the first quintade to 25% in the last quintade (Table 3), the task of promoting higher productivity through extension action in the Zimbabwean sugar industry is likely to require different implementation methods as well as being more difficult than in South Africa.

Benefit:cost ratio of technology

The decline in productivity over the study period results, inevitably, in a negative B:C ratio (Table 5). The ratio would be worse if the expenditure on technology had been higher but, ironically, productivity cannot be raised without sustained and higher expenditure on technology. This will be a problem for ZSAES policy makers, but their decisions could be facilitated by routine economic analysis of the factors that determine the B:C ratio of technology. Offensive research, that is, programmes or projects initiated with the express purpose of increasing productivity, was started at the ZSAES in 1976, only 13 years ago, when the first selections were made in the plant breeding programme. It is therefore premature to expect a positive B:C ratio. With hindsight, the policy decision to delay a start on plant breeding for ten years can be questioned, but the grounds for doing so were good; the Wilson report so recommended and the availability of varieties, apparently well suited to the environment, were available at no cost from South Africa.

Until 1976 the ZSAES was engaged exclusively in defensive research. Defensive research programmes are conducted to prevent yield decline, for example, monitoring and control of pests and diseases, testing 'imported' technologies and techniques such as varieties, chemicals, fertility maintenance and management. The importance of defensive research should not be underestimated. For example, in a field scale trial on Triangle, a yield increase of 3,69 tons ERC/ha in two ratoon crops was obtained by smut roguing in a defensive research programme (Anon, 1996-97). If the industry's average yield of 14 tons ERC/ha is reduced by 3,69 tons on five of the average seven crops (i.e. excluding the plant and first ratoon crops) the *potential* value of roguing can be calculated as about 19% of the industry's total crop value. However, the *actual* value of defensive research must be part of the total value attributable to technology, viz. Z\$m 109,05, and since its cost is only some 30% of total ZSAES costs, viz. Z\$m

43,03 (*personal communication) and because the B:C ratio for offensive research must be negative (yields have declined) the B:C ratio of defensive research would be at least +2,53.

Another important value attributable to technology which has not been taken into account in this study is the social benefit it generates. The social benefit created by the ZSAES's generation of technology is part of the social benefit created by the industry as a whole, namely, the value of the employment it creates, the foreign exchange it earns, as well as all the direct social benefits it provides such as housing, health and educational services. Many studies have indicated that the social benefit of research and development (R&D) is usually much larger than its private return. For example, in a tea industry study Donovan and Limwado (1995b) estimated the social return on tea research to be 44 times the private return.

Conclusions

The overall conclusions from this study are as follows:

There is a need to increase the ZSAES's plant breeding programme, i.e. its *offensive* research effort, if its benefits are to exceed its costs. The necessary changes in research priorities to do this were taken ten years ago, but for implementation it will also require a higher level of investment by the industry in the ZSAES. This investment has declined to very low levels in recent years and is now appreciably lower than in other commodity-funded research institutions in the region.

The value of *defensive* research is high albeit difficult to estimate accurately, but is probably two and a half times its cost. It would be useful for policy and management purposes to have a definitive estimate of the value of the ZSAES's defensive research input.

Improving the ZSAES's overall B:C ratio will also depend on reversing the serious decline in technology transfer (extension) effort that has taken place throughout the study period. This will be particularly important in promoting the rapid adoption of new technologies such as the locally bred and recently released varieties. A recent study (Donovan, 1998) has shown that the rapid adoption of a variety can be as important economically as its productivity advantage.

The B:C ratio is adversely affected if technical services are provided without charge or appreciably below cost. The trend elsewhere in agricultural R&D institutes is to charge for services so that research is not disadvantaged, but to do so at marginal (rather than total) cost because the facilities required to provide services are usually also used for research purposes.

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¹ Dr M Clowes, Director, ZSA Experiment Station.

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REFERENCES

- Anon (1994-95). Research Report of the Zimbabwe Sugar Association Experiment Station for 1994 and 1995.
- Anon (1996-97). Research Report of the Zimbabwe Sugar Association Experiment Station for 1996 and 1997.
- Cackett, KE (1990). Cane Production, Cane Quality and Mill Performance Data. 2nd Edition. Published by the Zimbabwe Sugar Association Experiment Station.
- Donovan, PA (1992). Technology sources and contribution to productivity in the South African sugar industry. *SA Journal of Science* 88: 300-303.
- Donovan, PA (1994). Report on Services to be offered by the Zimbabwe Sugar Association Experiment Station. Published by Zimbabwe Sugar Association.
- Donovan, PA (1998). The Value of N12 in the Midlands North Area. *Proc S Afr Sug Technol Ass* 72: 35-41.
- Donovan, PA and Cousins, LTV (1995). The sources and value of R&D in the Zimbabwe tobacco industry. Proceedings of the 25th Anniversary Symposium of the Crop Science Society of Zimbabwe, held in Harare, June 1995.
- Donovan, PA and Darroch, M (1991). Estimating returns on agricultural commodity extension. *Agricultural Systems* 37: 39-53.
- Donovan, PA and Limwado, G (1995a). The sources and value of R&D in the Malawian tea industry. Proceedings of the First Regional Tea Research Seminar held in Mulanje, Malawi.
- Donovan PA and Limwado, G (1995b). The social benefits of the Tea Research Foundation's R&D in Malawi. Proceedings First Regional Tea Research Seminar held in Mulanje, Malawi.
- Donovan, PA and Nieuwoudt, WL (1992). Estimating technology's contribution to productivity in the South African sugar industry. *Agricultural Systems* 39: 329-338.
- Musikavanhu, F (1998). The contribution of estates to sugar production in the Zimbabwe South Eastern Lowveld: 1970 to 1997. Proceedings of the Fourth Zimbabwe Sugar Seminar held at the Zimbabwe Sugar Association-Experiment Station.
- Schultz, TW (1953). *The Economic Organisation of Agriculture*. McGraw-Hill, New York.
- Wilson, J (1965). A report on the organisational requirements for agricultural research and specialist services in the Rhodesian sugar industry. Published by the South African Sugar Association Experiment Station.
- Zhou, M (1996). Sugarcane Selection 1976 to 1996. Information Bulletin No 1/96, published by the Zimbabwe Sugar Association Experiment Station.

APPENDIX 1

Data used in the Cobb-Douglas production function analysis

Year	Yield (ERC/ha)	Technology (Z\$/ha)	Water (mm)	Production cost index	Export price (Z\$/t sugar)	Area under cane (ha)
1970	14,17	376	1 998	469	1 268	13 710
1971	15,49	358	2 135	485	1 851	13 479
1972	14,17	346	1 822	441	2 453	15 457
1973	12,09	325	1 961	400	2 295	17 821
1974	14,36	297	1 990	395	5 345	17 260
1975	14,02	234	2 184	357	8 556	18 681
1976	14,12	344	2 521	435	3 381	16 939
1977	14,02	277	2 319	451	1 331	18 182
1978	13,19	244	2 125	407	2 347	19 443
1979	12,21	247	2 218	312	1 086	19 209
1980	13,94	268	2 094	279	6 124	21 480
1981	13,96	241	1 897	299	2 812	24 409
1982	13,34	290	1 942	341	2 378	24 746
1983	12,57	217	1 725	295	2 397	26 929
1984	14,01	192	1 895	262	2 341	26 846
1985	14,08	228	1 817	285	2 373	25 876
1986	15,58	217	1 760	301	2 178	26 796
1987	12,45	210	2 060	290	2 812	27 040
1988	13,80	252	1 846	333	3 391	25 058
1989	14,06	240	1 608	319	3 560	26 710
1990	13,56	255	1 498	288	4 135	26 338
1991	9,64	241	631	262	6 325	25 741
1992	0,05	133	984	150	6 475	10 565
1993	5,28	571	5 720	531	8 244	5 780
1994	14,10	187	2 055	310	4 107	26 222
1995	13,65	155	1 593	259	4 602	26 310
1996	9,24	210	1 788	261	5 239	25 891