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THE RATE OF RETURN ON R&D IN THE SOUTH AFRICAN SUGAR INDUSTRY, 1925-2001

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Abstract

The rate of return (ROR) on R&D in the South African Sugar Industry is estimated from a Ridge Regression of a production function of time series data for the period 1925 to 2001. The Industry has kept records on R&D expenditure, yields, rainfall and related factors over a 75-year period. Sugar cane yield was measured in tons sucrose to account for quality improvement. In this function, R&D expenditure lagged three years was significant (t = 6.5) in explaining increased sucrose production per ha. Other highly significant variables in this model were rainfall (t = 5.2) and real cost of production (t = 8.4). A dummy interaction with R&D was significant (t = 2.9) implying a greater impact for R&D technology during the period 1959 to 1975 than either before or after this period. The standardised regression model indicated that the R&D variable was one of the most important variables in explaining yield. Using the elasticity of production estimate for the R&D variable of the un-standardised model, a Benefit/Cost ratio for this variable of 1.41 was estimated, if benefit of millers is excluded and 1.59, if the gain to millers is included. In the latter estimates, the exports realisation price of sugar was used as the appropriate shadow price. A real internal rate of return was estimated at 17%. A unique feature of the South African Sugar Industry is that research is privately funded by the industry, which implies that the distortionary impact of taxes need not be accounted for, as is the case with public funded research.

1. INTRODUCTION

Several studies measuring the return on R&D in agriculture have appeared in recent years in South Africa (Townsend & Van Zyl, 1998; Thirtle *et al*, 1998; Mokoena *et al*, 1999; Townsend *et al*, 1997; Khatri *et al*, 1996; Donovan, 1989) and internationally (Alston *et al*, 2000; Chavas & Cox, 1992). Different methodologies have been used in studies all showing a high rate of return.

In this contribution the rate of return (ROR) on R&D in the South African Sugar Industry is researched using data for the period 1925 to 2001. ROR estimates are based on a production function using Ridge Regression of time series data. In these estimates sugar cane is valued at its shadow price (export realization price)

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as local prices are somewhat higher than world prices. The Industry has kept records on R&D expenditure, yields, rainfall and related factors over a 75-year period. A further advantage in studying these data is that sugar is a homogeneous product (no quality change problem) and that the research was largely conducted by one organisation. The study thus does not suffer from major aggregation problems and specification bias, which is the case if many products are studied. A spillover of R&D in this industry is that millers also benefit.

A unique feature of the South African Sugar Industry is that research is privately funded by the industry, which makes the industry probably the only completely private service provider in a South African or African context. Pasour (1990) contents that high ROR estimates from public funding should consider the distortionary impact of taxes, which is not a problem in this case.

2. OTHER STUDIES

In an exhaustive report (Alston *et al*, 2000), the International Food Policy Research Institute reviewed 294 studies of returns on agricultural R&D investments. This report represents nearly the entire literature and contains over 1,800 separate estimates of rates of return in both developed and developing countries. After eliminating extremes, returns averaged 88% on research investments alone, 79% on extension alone and 45% on research and extension combined. The explanation given for the lower estimate for the combination is that the corresponding studies captured more of the total costs of the technology innovation process. Traxler and Byerlee (2001) estimate the IRR on wheat improvement research in India as 55%. It is not always clear how these estimates were made, for instance in the Traxler and Byerlee (2001) study it is not stated whether there are price distortions in the wheat market.

Studies in South Africa indicated the following estimates for ROR; 51% for dairy cattle, 44% for beef cattle (Mokoena *et al*, 1999). In this study estimates were based on demand and supply elasticities and a shift in the supply function. Townsend and Van Zyl (1998) estimated ROR in wine and grape research in South Africa at 40% using a production function. Thirtle *et al*, (1998) reported ROR on the research of the South African Agricultural Research Council (ARC). Several studies are reported, using different methodologies and studying various products. ROR varied from 5% to 100% with most estimates in the range 28% to 60%. Townsend *et al*, (1997) report ROR for maize research between 28% and 39%.

The internal rate of return (IRR) on agricultural R&D has been estimated in most studies as high. Pasour (1990) questions the high IRR estimated in most studies, as the distortionary impact of taxes used to fund the research is not considered.

That is assuming that research is public funded.

3. METHODOLOGY

Various techniques have been used to measure the ROR on R&D such as a profit function, economic surplus, distributed lag supply response, production functions, error correction model etc. The appropriate technique depends on available data. In this study the traditional production function approach has been used.

In a pioneer paper on R&D estimation Griliches (1958) used a production function approach. This approach has also locally been used by Townsend and Van Zyl (1998). The progress in the field of R&D estimation is documented in Alston *et al*, (1995). In the production function approach actual data are used and not experimental data while no assumption about elasticities are necessary to measure surplus areas. The Sugar Industry does not only produce a homogeneous product but the area is also fairly homogeneous and relatively affected by similar climatic conditions. Rainfall data were also available over the entire period.

In the production function the following time series data were used where the dependent variable Y = estimated yield of sucrose in tons per ha in the South African Sugar Industry, R&D = real expenditure on R&D in Rand per ha, lagged three years, Rain = annual rainfall in millimetres, Cost = production cost of capital and labour per ha, in Rand (real terms), Land = land under cane in hectares, while Dummy = 1 for 1959 to 1979, otherwise zero. A quality adjustment to yield data was made by measuring yield as tons of sucrose. As yield is measured per ha land should not have an effect on yield but it was hypothesised that over time as the industry expands less productive land will come into production. Data for the period 1925/26 to 2000/01 were obtained from Schmidt (2002), Fenwick (2002) and Donovan (1989). Different lag periods on R&D expenditure were used while Nerlove distributed lag models were also tested. The latter models assume a declining impact of R&D over time without specifying a specific period.

OLS and Ridge Regression are used in this section to study the rate of return. As Ridge Regression is less known some of the theoretical issues pertaining to the technique will be mentioned. In this regression a small bias is introduced in the correlation matrix at the expense of having more precision. If an estimator has a small bias and is more precise than an unbiased estimator, it may be preferred, since it will have a larger probability of being close to the true parameter value. The Mean Square Error ($Bias^2$ + Variance) may be lower if bias increases, but variance is reduced by more.

The ridge standardised regression estimators are obtained by introducing into the least squares normal equations a biased constant c>0.0, in the following form: $b^R = (r_{xx} + c\mathbf{I})^{-1} r_{xy}$ where b^R is the vector ((p-1)*1) of the standardised regression coefficients (p-1 coefficients) and **I** is the (p-1)(p-1) identity matrix. The correlation transformation (r_{xy}), which is a modification of the usual standardisation of a variable, is used above. The bias component of the total Mean Square Error of the Ridge Regression estimator increases, as c gets larger, while the variance component declines.

4. RETURN TO RESEARCH AND DEVELOPMENT (R&D)

4.1 Ordinary Least Squares Analysis (SPSS Software)

The impacts of R&D on sugar cane yields were studied in production function (1) (standardised form) based on the period 1925/26 to 2000/01.

$$\log Y = +\ 0.555 \log R\&D + 0.242 \log Rain + 0.849 \log Cost$$

$$\qquad (t = 3.1) \qquad (t = 5.3) \qquad (t = 5.1)$$

$$- 0.584 \log Land + 0.170\ (Dummy) * (\log R\&D) \tag{1}$$

$$\qquad (t = -3.1) \qquad (t = 3.5)$$

$R^2 = 0.866$
DW = 1.605
df = 67

Where:

Y = estimated yield of sucrose in tons per ha, R&D = as real expenditure on R&D in Rand per ha, lagged three years, Rain = annual rainfall in millimetres, Cost = production cost of capital and labour per ha, in Rand (real terms), Land = land under cane in hectares, Dummy = 1 for 1959 to 1979, otherwise zero.

All the parameters have t-values, significant at least at the 1% level while the R^2 is good (R^2 = 0.87). The Durbin-Watson statistic is in the zone of indecision, so no remedial measures were taken. Further, the DW variable is not really applicable since a dummy is used. All variables estimated have signs expected based on economic theory.

Yield of sucrose in tons per ha was significantly affected by R&D technology (lagged 3 years), expenditure per ha, capital and labour cost per ha, rainfall and land under cane. As this function is in standardised form the magnitude of the coefficients indicates the relative importance of each variable in explaining Y. This shows that R&D is important, as the coefficient is large. Variables were measured as logarithms (base 10), which means that coefficients are also elasticities.

The R&D variable was measured as real expenditure on R&D in Rand per ha lagged three years. This variable was highly significant (t = 3.1). Longer and shorter lagging periods were considered but a three-year lagging period produced the best overall results. This indicates a short lag period between technology investment and adoption.

In the above model it was further tested whether the impact of R&D changed during the period. An interaction term between a dummy (Dummy = 1 for 1959 to 1979, otherwise zero) and the technology variable indicated that R&D had in fact a greater impact during the period 1959 to 1979. This time period was chosen upon studying the Fourier Analysis of detrended technology – it can be seen that during 1959 to 1979 there is a change in the technology variable. (This was done using Statistica Version 6.0, 2002 software). The aim with Fourier Analysis is to transform a time series of data with cyclical components into a few underlying sinusoidal (sine and cosine) functions of particular wavelengths. The same periods would be chosen on studying the error terms of a model, where the R&D interaction term (with a dummy) was left out.

The contribution by capital and labour was captured in the production cost per ha variable, which was highly significant (t = 5.1). The land variable is negative (t = -3.1). This allows for the possibility that yields per ha (Y) may fall as additional land with lower potential is brought into production. This is due to the fact that additional land may have lower fertility, greater slope and poorer accessibility. The land variable is shown in a further analysis (Ridge Regression) to be unstable and no firm conclusions about this variable=s contribution can thus be made.

Cane yields are sensitive to rainfall (t = 5.3), as was dramatically illustrated during 1992/93 and 1993/94 when yield fell to the lowest in 50 years due to drought. Excessive rain or excessive nitrogenous fertiliser may, however, reduce sucrose yield, though usually not total yield. Rainfall is not correlated with the other independent variables and, therefore, does not contribute towards multicollinearity.

Multicollinearity is often a serious problem in time series data. Multicollinearity may unduly influence the least squares estimates if the maximum Variance Inflation Factor (VIF) is greater than 10.0 (Gujarati, 1995:387). The VIF for the land (17.6), cost (13.8) and R&D (15.8) variables are high and Ridge Regression is used as a remedy in the next section.

4.2 Ridge Regression (RR)

In RR a biasing constant is added to the correlation matrix to reduce multi-collinearity. A commonly used method of determining the biasing constant is based on the Ridge trace and the variance inflation factors. The Ridge trace plots the p-1estimated standardised regression coefficients for different values of c from 0 to 1.0. The smallest value for c is chosen where regression coefficients stabilise. In the above study a Ridge trace is used and it was observed that the regression coefficients stabilised at c = 0.15.

The parameters shown in equation (1) are estimated using Ridge Regression in the following standardised regression model (model 2) where c = 0.15.

$$\log Y = +\ 0.3036 \log R\&D + 0.2241 \log Rain + 0.4036 \log Cost$$
$$(t = 6.5) \qquad (t = 5.2) \qquad (t = 8.4)$$

$$+\ 0.08513 \log Land + 0.1286\ (Dummy) * (\log R\&D) \qquad (2)$$
$$(t = 1.9) \qquad (t = 2.9)$$

$R^2 = 0.834$
df =67

If models (1) and (2) are compared, then it can be seen that the precision of the R&D variable increased (from a t-value of 3.1 to 6.5) while R^2 declined somewhat. It is a common occurrence in Ridge Regression for the coefficients to change signs at higher levels of c. In fact, the sign of the land variable becomes positive, as c increases.

The regression coefficients are elasticities, as the logarithms of variables are used. For instance, a 1% increase in R&D spending (real expenditure on R&D in Rand per ha, lagged three years) is estimated to increase sucrose yield (tons per ha) by 0.432% (0.3036 + 0.1286) for the period 1959 to 1979. The elasticity for the remainder of the period studied (1925 to 2001) was lower at 0.304. It appears as if R&D spending at first (1925 to 1958) had a relatively smaller impact on research (elasticity = 0.304), while the impact increased during the period 1959 to 1979 (elasticity = 0.432) and that it declined again (elasticity = 0.304) during the latter period (1980 to 2001).

The variables are again expressed in standardised form (deviation from the mean expressed as units of its standard deviation). The large magnitude of the regression coefficient for the R&D variable thus indicates that this variable is relatively important in explaining Y. From model 2, it appears that the R&D

variable is more important than the Rain variable in explaining Y. Furthermore, the R&D variable was more important than the Cost variable for the period 1959 to 1979, but less important than Cost for the remainder of the period.

4.3 Benefit/Cost of R&D

An attempt was made to estimate the Benefit/Cost ratio of an investment in R&D in the South African Sugar Industry. It is important that the parameters of the un-standardised model be used (the same t- values and R^2 apply for this model as for the standardised model) as the raw data are in un-standardised form. The production elasticities in the un-standardised model are 0.07640 (1925 to 1958), 0.1057 (1959 to 1979) and 0.07640 (1980 to 2001).

In the calculation of the Benefit/Cost ratio of R&D, the production elasticity based on period 1980 to 2001 (most recent period) is used, while all other data (cost, income and yield) refer to the period 1998/2001.

<u>Cost</u>:
1% of R&D = R480,811.

<u>Benefit</u>:
0.07640% of Benefit = (.0007640)*(Average yield in metric tons sucrose per ha)*(ha under sugar cane)*(export realisation price per ton sucrose minus production cost minus cost of harvesting minus cost of land) = (.0007640) (6.95) (424219) *(R302 - R744.89 - R250.75 - R5.76) = R677,107.

The Benefit/cost ratio is derived as (R677,107)/R480,811 = 1.41, implying that a R1 investment in R&D leads to a R1.41 return. This implies that the return on R&D is high, as a return in excess of 1.0 indicates an economic feasible investment. In this calculation, the export realisation price for sugar (world price is the shadow price in CB analysis for tradable goods) is used, which is significantly lower than the average price that farmers receive. CB analyses also require opportunity cost pricing of all inputs. For the purpose of this study shadow cost pricing on inputs was not undertaken. Import tariffs on most farm inputs have been phased out; the main remaining tariff is on importation of petroleum.

Harvesting cost is estimated at R29.5 per ton cane or R250.75 per ton sucrose (Sugden, 2002). The opportunity cost of land needs to be considered. The best alternative use of sugar cane land in KwaZulu-Natal is probably grazing with a rental rate of R40 per ha or R5.76 per ton sucrose.

Spillovers need to be considered. Millers gain from increased sugar production in the short run, as the capacity utilisation of mills was low during the early 1990's. The miller profit from increased mill-turnover has been estimated as a margin/ton sucrose for two mills; Amatikulu R22.2 and Sezela R30.0 (Erasmus, 1995). In the long run all costs are variable and the marginal milling profit will be less. Using the data from Erasmus (up dated using the producer price of sugar cane), the benefit estimated to growers needs to be adjusted for a miller profit of R88,186. If this figure is added to the benefit estimated in 4.3, then a R1 expenditure on R&D is expected to lead to a total return to growers, millers and consumers of R1.59.

In this study the technology lag of R&D was estimated as three years implying that the internal rate of return is about 17% in real terms (as data were adjusted for inflation using 1985 as base period = 100). This can be compared with real discount rates in the South African economy of about 5% to 8%. The real discount rate in South African Agriculture has been estimated at about 5% (Nieuwoudt, 1980). Recent data (2003) on land rents and land values observed by the authors indicate that this figure may have increased to about 6%. A further confirmation of this number is that actuaries used a 5% real discount rate in 1995 to calculate the value of pensions of members (which include all university staff) of the government pension scheme (AIPF).

Although the rate of return estimated in the South African Sugar Industry of 17% is high compared to its opportunity cost, it appears low compared to rates reported in other studies. An explanation may be offered for this anomaly. Research, training and extension are integrated at the Experiment Station, thus capturing a greater proportion of the total costs of the technology innovation process. An exception is a study by Chavas and Cox (1992) who estimated the internal rates of return to be 17% for private research in the United States agricultural sector, a rate identical to that calculated above. Nevertheless; it is difficult to compare precisely the rate of return estimated for the sugar industry in South Africa to values found for other commodities and for countries. Too many factors play a role in determining the rate of return.

This estimate is lower than ROR estimates undertaken in other studies in South Africa (Thirtle *et al*, 1998; Townsend & Van Zyl, 1998; Mokoena *et al*, 1999).

4.4 Welfare redistributional impacts

R&D in the Sugar Industry may impact directly on the following parties; large scale farmers, small scale farmers, millers and consumers (wealthy versus poor). Other impacts are on labour employment, agri-business sector (input suppliers) and exports (foreign exchange). No attempt was made to estimate the spillover impacts on labour employment and the agri-business sector (input suppliers) and estimates of the rate of return are likely to be an underestimate.

4.4.1 Producers, consumers and millers

If the product demand elasticity is less than one, consumers gain from research, while farmers lose. SA exports sugar and an increase in production causes larger exports, without affecting domestic prices. South African consumers are thus unlikely to gain from additional R&D in the South African Sugar Industry. In this study the consumer surplus (area under the demand) was thus not measured as a measure of benefit (welfare). The consumer surplus of all items exceeds the budget constraint, which makes this concept in any case controversial. The gain to producers is reflected by the increase in export revenue.

4.4.2 Small-scale versus large-scale growers

According to Sugden (2002) there are 51 000 small-scale producers of whom 32,000 deliver cane. At present, large-scale commercial farmers are the main beneficiaries from R&D. However, with the increased numbers of small growers, this group will increasingly benefit from R&D.

The technology transfer lag may be shorter in a commodity organisation, than when R&D and extension are separated. The technology transfer lag in the South African Sugar Experiment Station with an integrated extension service was estimated at only three years in this document. This compares with a 5-7 year lag in research organisations without integrated extension (Donovan, 1989). The short lag period of three years may be further explained by the fact that research done by the Experiment Station is of an applied nature. Furthermore, the education level of South African commercial farmers is relatively high. The lag for basic research can be expected to be long.

5. SUMMARY AND CONCLUSIONS

In order to estimate the impact of the R&D technology developed at the Station on yield of sucrose, a production function was fitted (using Ridge Regression, c = 0.15) for the years 1925/26 to 2000/01. In this function, R&D expenditure lagged three years was significant (t = 6.5) in explaining increased sucrose production per ha. Other highly significant variables in this model were rainfall (t = 5.2) and real cost of production (t = 8.4). A dummy interaction with R&D was significant (t = 2.9) implying a greater impact for R&D technology during the period 1959 to 1975 than either before or after this period. The standardised regression model indicated that the R&D variable was one of the most important variables in explaining yield. Using the elasticity of production estimate for the

R&D variable of the un-standardised model, a Benefit/Cost ratio for this variable of 1.41 was estimated, if benefit of millers is excluded and 1.59, if the gain to millers is included. In the latter estimates, the exports realisation price of sugar was used as the appropriate shadow price. The technology lag was estimated as three years in the regression model, which indicated a real internal rate of return of 17%. High returns on investment in R&D as reported in some studies raise questions about methodologies used, assumptions made and who funded the research etc.

REFERENCES

ALSTON JM, MARRA MC, PARDEY PG & WYATT TJ (2000). Research returns redux: A meta-analysis of the returns to agricultural R&D. *The Australian Journal of Agricultural and Resource Economics* 44(2):185-215.

ALSTON JM, NORTON GW & PARDEY C (1995). *Science under scarcity: Principles and practice for agricultural research evaluation and priority setting*. Cornell University Press, Ithaca and London.

CHAVAS JP & COX TL (1992). A nonparametric analysis of the influence of research on agricultural productivity. *American Journal of Agricultural Economics* 74:583-591.

DONOVAN PA (1989). *Returns on agricultural research and development in the South African Sugar Industry.* Unpublished PhD Thesis, University of Natal, Pietermaritzburg.

ERASMUS J (1995). *Economic evaluation of a transport development programme for small-scale cane growers*. Unpublished M Agric Mgt Thesis, University of Natal, Pietermaritzburg.

FENWICK L (2002). *Private communication*. South African Cane Growers Association. Durban.

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

GUJARATI D (1995). *Basic econometrics*. New York: McGraw-Hill, Inc.

KHATRI Y, SCHIMMELFENNIG D, THIRTLE C & VAN ZYL J (1996). Refining returns to research and development in South African commercial agriculture. *Agrekon* 35(4):283-290.

MOKOENA MR, TOWNSEND RF & KIRSTEN JF (1999). Cattle improvement schemes in South Africa: Measuring the returns to research investments. *Agrekon* 38(1):78-89.

NIEUWOUDT WL (1980). Value and rent of farmland. *South African Journal of Economics* 48:389-397.

PASOUR EC Jr (1990). *Agriculture and the State*. Holmes & Meier, New York.

SCHMIDT E (2002). *Private communication*. South African Sugar Association Experiment Station. Mount Edgecombe.

SUGDEN B (2002). *Private communication*. South African Cane Growers Association, Durban.

THIRTLE C, TOWNSEND RF, AMADI J, LUSIGI A & VAN ZYL J (1998). The rate of return of expenditure of the South African Agricultural Research Council (ARC). *Agrekon* 37(4):621-631.

TOWNSEND RF & VAN ZYL J (1998). Estimation of the rate of return to wine grape research and technology development expenditures in South Africa. *Agrekon* 37(2):189-210.

TOWNSEND RF, VAN ZYL J & THIRTLE C (1997). Assessing the benefits of research expenditures on maize production in South Africa. *Agrekon* 36(4):585-597.

TRAXLER G & BYERLEE D (2001). Linking technical change to research effort: An examination of aggregation and spillovers effects. *Agricultural Economics* 24:235-246.