Economic Rate Of Return To Plum Research Investments In South Africa

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Abstract

This paper briefly presents the results of a production function approach study of South African plum industry and estimates the rate of returns to research investments. In the climate of declining agricultural research investments, it is paramount to provide evidence of the benefits of research and substantiate the need for increased investments. The lag length between research investments and production output was found to be 10 years using OLS regression. The marginal rate of return to plum research investments, calculated based on the results was estimated at 14.23 per cent. Our findings indicate that research and development investments for plums were beneficial.

Introduction

Several studies have shown that investing in agricultural research and development has greatly enhanced global agricultural productivity (Pardey *et al*., 2012). In South Africa, numerous studies (Liebenberg, 2011; Townsend *et al*., 1998; Thirtle *et al*., 1998) provide evidence that confirms the internationally recognised conclusion that continued investments into agricultural research and development (agR&D) have yielded huge benefits to the agricultural sector. Whilst it is now widely recognised that in order to increase agricultural productivity more investments have to be channelled towards agR&D, very little is known about the rate of return (ROR) to investments made into different agR&D initiatives especially in the deciduous fruit industry in South Africa.

Continued investments in agricultural research and development in deciduous fruits have led to the development of over 300 improved deciduous fruit cultivars, which have contributed positively to the growth of the industry and improved food security. For example, in 2007, 54 908 tons of plums were produced and the industry employed 5 907 labourers (permanent equivalent) who had 23 630 dependents. By 2013, 81 419 tons of plums were produced and in turn the industry employed 7 049 labourers who had 28 195 dependents. This has meant that more families have increased their income, allowing them to invest in better nutrition and food security. Yet very little is known about the

economic benefit of the Agricultural Research Council's (ARC) plum fruit research initiatives in South Africa - the major research organization that does plum breeding research in the country.

It is therefore paramount that the rate of return to research is determined in order to inform R&D decision-makers of the importance of public support for agricultural research and to substantiate the need for more investment in existing plum breeding and other plum research programmes. Showing research impacts is important to ensure an appropriate level of public support. Without clear and convincing evidence of its benefits, research will not be able to attract the necessary funding required for it to be successful.

Why rate of return studies?

Since 1955, there have been hundreds of studies published reporting on what the benefits from agricultural research and development investments have been. These studies are carried out for internal and external stakeholders of the research institutes. Internal stakeholders are the researchers themselves, who require information on what the economic impact of their work has been on the targeted population so as to support their decision-making process on whether or not to adjust resource allocation across programmes. The external stakeholders include the governments and other funders of the research in order to provide accountability for the funds they invest. In the current climate of increasing competition for funding and declining funds, much effort has been put into demonstrating to the external stakeholders what the results of the research investments have been.

Rate of return studies can be classified as *ex-ante* and *ex-post* evaluations. *Ex-ante* studies are conducted before projects or programmes have been undertaken and generally make use of experimental data provided by scientists to forecast the performance of the product. On the other hand, *ex-post* evaluations are undertaken after diffusion of research has been initiated and are based on the actual data collected on the ground. *Ex-ante* studies are usually done to help the researchers in setting priorities, whilst ex-post studies generate information that is useful for the selection, planning and management of future research programmes. The approaches employed in measuring both impacts are essentially the same. This study will focus on *ex-post* economic impacts.

The first effort of measuring the returns to research was made in 1953 by Professor Schultz. He evaluated the value of inputs saved as a result of improved production techniques in agriculture. Griliches followed in 1958 when he attempted to estimate the realized social rate of return in hybrid-corn research. Numerous studies have been conducted thereafter, and the evidence is unambiguous, showing that the rate of return on agricultural research is high. Most of these studies are *ex-post* and are based on secondary data. Table I below shows an overview of studies estimating the rate of return to research in South Africa.

Table I: Estimated Rates of return (ROR) to agricultural research for South Africa

Study and period	Time period	Annual rate of return (percent)
Aggregate, 1993 (Thirtle, Von Bach and Van Zyl)	1955-1991	64
Agregate, 1996 (Khatri, Thirtle, Van Zyl)	1947-1991	44
Crops, 1996 (Van Zyl)	1947-1991	30
Horticulture, 1996 (Van Zyl)	1947-1991	100
Animals, 1996 (Van Zyl)	1947-1991	5
Maize, (Townsend, Van Zyl and Vink)	1950-1995	29-39
Wheat, (Thirtle, Van Zyl and Vink)	1950-1995	28-34
Sorghum, (Thirtle, Van Zyl and ink)	1950-1995	50-63
Groundnuts, 1997 (Thirtle, Townsend and Van Zyl)	1968-95	50
Tobacco, 1997 (Thirtle, Townsend and Van Zyl)	1965-1995	50-53
Sweet potatoes, 1997 (Thirtle, Van Zyl and Townsend)	1952-1994	21
Animal Production, 1998 (Townsend and Thirtle)	1947-1994	11-16
Wine grapes, 1997 (Townsend and Van Zyl)	1987-1996	40-60
Crop cover management, 1997 (Thirtle and Townsend)	1986-1997	44
Bananas, 1997 (Thirtle, Townsend and Van Zyl)	1953-1995	50
Deciduous fruits, 1997 (Thirtle, Townsend and Van Zyl)	1965-1994	78
Lachenalia, 1997 (Niederwieser, *et al.*)		6.5-12
Protea, 1997 (Wessels, *et al.*)		8

Adopted from: Thirtle, Townsend, Amandi, Lusigi and Van Zyl (1998)

Various techniques were used in the studies above, and these included the economic surplus model, error correction model, and production functions model, just to mention a few. It is evident that investment in agricultural research in South Africa has been worthwhile.

Approaches to measuring ex-post economic impacts of plum research

Ex-post economic impacts of agricultural R&D investments have been estimated using a number of methods, namely: congruence, supply response, scoring, benefit–cost analysis, total factor productivity, error correction models, economic surplus models and the production function approach. The two main approaches that are common in literature are the economic surplus approach and the production function approach. Each of these is discussed in detail below.

According to Alston *et al.* (1995) the economic surplus approach starts by recognizing that production levels depend on the use of a wide range of inputs, such as land, labour, seeds, fertilizers and chemicals. It goes on to express the level of production as a function of price, which predicts that as the price of plums increases, the level of production will be higher. Again, the same approach is used with demand to determine the equilibrium price and quantity. In this case the function predicts that, as the price of the good increases, the quantity consumed decreases.

How will research affect this economic surplus? Research will result in the increase in the quantities produced while the prices remain the same, thus shifting the supply curve to the right and shifting the equilibrium to a lower price. This shift in the supply curve will represent the aggregate effect of farm-level yield gains due to improved technologies.

The initial price, and the quantity supplied and demanded, are represented by P and Q respectively, as shown in Figure 1 below. With the adoption of new yield-enhancing and cost-reducing improved technologies, the supply curve will shift to the right, resulting in a new equilibrium. At this new equilibrium, price and quantity will be represented by P′ and Q′ respectively. The impact of research on producers is that aggregate supply increases

while costs remain the same, as a result the production costs will be reduced. This is shown in Figure 1 below as area **A** minus area **B**. Consumer surplus is the area below the demand curve and above the relevant price horizontal. The gains in consumer surplus will be depicted by area **B** plus area **C**. The impact of research on the economy as a whole is represented by area **A** plus area **C**.
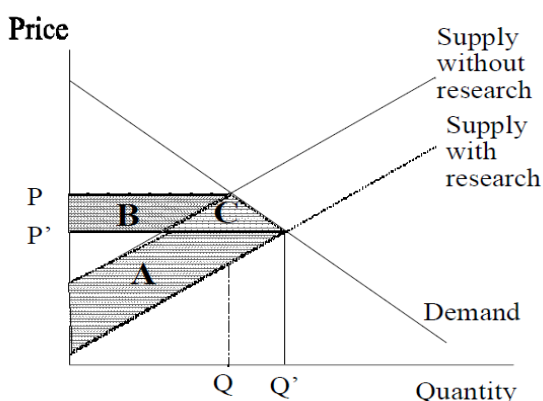

Figure 1: Economic surplus (producer and consumer surplus)
Source: Masters *et al.* (1996)

The production function approach

In the production function approach, parameters of a single commodity are estimated. Here, agricultural research and extension are the explanatory variables. It is assumed that investment in research creates technological changes which in turn affect production and/or productivity. These changes have a considerable time lag attached to them and, therefore, time series data are required.

According to Alston *et. al* (1995), investments in agricultural research result in the production of knowledge which, in turn, results in increased productivity. The relationship between research investment and the stock of useful knowledge is known as the knowledge production function. According to this function, the benefits from research-induced changes in knowledge are: more outputs for a given expenditure of inputs, cost

saving for a given quantity of output, and new and better products. Current knowledge refers to capital stock from past investments and will determine the rate of production of new knowledge. Thus, productivity in a given year does not depend on the current level of R&D investments, but rather on the stock of knowledge derived from past expenditure. This is because there is a time lag before an investment can be converted into useful knowledge that can be adopted by farmers.

The Cobb-Douglas production function approach is commonly used to estimate the rate of return, mainly because of its simplicity and straight forward transparency in which the estimated parameters can be used to quantify the economic effects of interest. This production function assumes homogeneity, unitary elasticity of substitution between inputs, and separability. In this approach, the marginal rate of return on research is estimated by using research expenditure as a variable of the production function in order to measure the impact of research on output. The basic model used in the production function approach can be expressed as:

$$Q_t = A \prod_{i=1}^{m} X_{it}^{\beta} \prod_{j=0}^{n} R_{t-j}^{\gamma} e^{u} \tag{1}$$

Where:
Qt = value of output in year t,
A = a shift factor,
Xit = value of ith conventional input in year t,
Rt-j = research and extension expenditure in the t-jth period,
β and γ are parameters, and
u is the random error term.

The equation above is mainly used for cross-sectional data. The length and shape of the time lag of impact of research expenditure on output varies. In some cases the effects of research on productivity are seen over a period of between 12 to 15 years. The effect of research on productivity may be small in the first years, but with time more producers have access to research results for adoption, and the effect to productivity increases.

However, when a longer period has elapsed, the impact of the improvement may decrease, which is known as diminished returns.

For time series data, Norton and Davis (1981) noted that:

$$P = AW^\gamma E^\epsilon \prod_{j=0}^{n} R^{\alpha t\text{-}j}_{t\text{-}j} e^v \tag{2}$$

Where P is the productivity index of agricultural output, W is a weather index, E is the education level of the farm workers, and γ and ϵ are productivity coefficients for the associated inputs. The productivity index is mainly used when there is a lack of sufficient data on the important conventional input and because it helps avoid the occurrence of multicollinearity problems that are associated with time series data. Weather is included because it explains some residual errors. The education level of farmers (E) is used as it affects their creative and managerial abilities, as well as their abilities of rationally assessing and adopting new technologies.

The advantage of using the production function approach is that it allows the measurement of the marginal rate of return, as opposed to the economic surplus model, which only measures the average rate of return. The other advantage of the production function approach is that it assigns weights in terms of how much each input contributes towards the total return (Khan and Akbari, 1986). Another advantage of this approach is that it can be extended to include technology variables that shift the production function. It is also preferred because it is inherently difficult to measure the output of R&D directly, but when stock of knowledge is used it becomes easier to measure by means of information available in publications. Also, the knowledge produced is incorporated in new technologies, making patents another useful measure of the R&D output.

Model specification

The production function for plums in this study was specified as

$$Y_t = f(W, F, A, RD) \tag{3}$$

Where Y_t is the yield of plums in tons per ha, W is the weather index, F is the fertilizer price index, A is the area planted and RD is the research expenditure. The variables will be expressed in the form of natural logarithms (*ln x*), in order to have coefficients as elasticities. To have the effects of R&D expenditures lagged by up to a certain number of years. The resulting equation will be:

$$\ln Y_t = \ln\beta_0 + \ln\beta_1 W + \ln\beta_2 F + \ln\beta_3 A \ \sum_{i=1}^{n} \beta j RD_{t-l} + u_t \qquad (4)$$

where n is the maximum lag length which affects the yield, and ut is the disturbance term which accounts for the variations in yield not explained by the model.

As explained by Townsend and Van Zyl (1998), each lag coefficient β_i is the output elasticity of R&D for that year and is given by:

$$B_i = \frac{\partial \ln OUTPUT_t}{\partial \ln RD_{t-i}} = \frac{\partial OUTPUT_t}{\partial RD_{t-i}} \times \frac{RD_{t-i}}{OUTPUT_t} \qquad (5)$$

Thus the marginal physical product of R&D is the elasticity multiplied by the average physical product:

$$MPP_{t-i} = \frac{\partial \ln OUTPUT_t}{\partial \ln RD_t} = \beta \frac{OUTPUT_t}{RD_{t-i}} \qquad (6)$$

Replacing YIELD/RD$_{t-i}$ by its geometric mean and changing from continuous to discrete approximations gives:

$$\frac{\Delta OUTPUT_t}{\Delta RD_{t-i}} = \beta i \frac{\overline{YIELD}}{\overline{RD_{t-i}}} \qquad (7)$$

Then, multiplying by the increase in the value of output divided by the change in quantity converts from output change in quantity to output value. Hence the value marginal product of R&D in period t-i is given as:

$$VMP_{t-i} = \frac{\Delta VALUE_t}{\Delta RD_{t-i}} = \beta i \frac{\overline{OUTPUT}}{\overline{RD_{t-i}}} \times \frac{\Delta VALUE_t}{\Delta OUTPUT_t} \qquad (8)$$

Where Yield/RD$_{t-i}$ is an average, and ΔValue$_t$/ΔYield$_t$ is calculated as the average of the last five years minus the average for the first five years, due to the fluctuations. ΔValue$_t$/ΔYield$_t$ and Yield/RD$_{t-l}$ are constant price geometric averages. The marginal internal rate of return (MIRR) is then calculated from:

$$\sum_{i=1}^{n} \frac{VMPt-1}{(1+r)} - 1 = 0 \tag{9}$$

Where n is the lag length. By solving for r the MIRR will be obtained.

Definition of data

For the production function in this study, the dependent variable will be Y_t which will be the total yield of plums in tons per ha. The independent variables will include: R&D expenditure given by the real values of R&D costs in South African Rands, lagged, conventional inputs represented by the fertilizer price index and the area planted, and uncontrolled factors represented by the weather index W.

Output data were obtained from the Deciduous Fruit Board annual reports and *Key deciduous fruit statistics*. To obtain yield, the quantity of plums produced was divided by the total area used for plum production. The area data were collected from various annual reports of the Deciduous Fruit Board and from Key Deciduous Fruit Statistics. Fertilizer price data were adopted from the South African Wine Industry Information & Systems NPC (SAWIS). Weather data were collected from the South African Weather Service. Research expenditure data were collected from the Agricultural Research Council's Infrutec, finance database as well as the Unifruco Research Services financial statements.

Rate of return results

The variation in plum production is explained by changes in weather, fertilizer prizes, area planted and investment in R&D. Equation 4 was used to determine the lag structure. The lag coefficients were estimated using the polynomial functional form (lag structure). The Ordinary Least Squares regression was performed on Eviews 8. The R&D variable it was

differenced once to make it stationary. A second degree polynomial with both near and far end of the distribution constrained to zero, was fitted at various lag lengths from 4 to 26. The 10th lag was selected as it appeared to be reliable due to its superior t, F and Durbin-Watson statistics.

TABLE II

TEN-YEAR R&D POLYNOMIAL DISTRIBUTION LAG MODEL (PDL)

Variable	Coefficient	t-Statistic
C	-12.58254	-2.187053
LW	0.039151	0.291647
LA	2.097594	-2.550751
LF	0.874211	4.933014
RD	0.09839	3.14244
RD_{t-1}	0.17889	3.14244
RD_{t-2}	0.24151	3.14244
RD_{t-3}	0.28623	3.14244
RD_{t-4}	0.31307	3.14244
RD_{t-5}	0.32201	3.14244
RD_{t-6}	0.31307	3.14244
RD_{t-7}	0.28623	3.14244
RD_{t-8}	0.24151	3.14244
RD_{t-9}	0.17889	3.14244
RD_{t-10}	0.09839	3.14244
Sum (RD)	2.55819	3.14244
Adjusted R-squared	0.872912	
Durbin-Watson stat	1.975912	

Source: Eviews results.

Table II shows that there is no lead time with R&D having an impact in the current year.

This may reflect the direct effect of maintenance research that is conducted at Infruitec. These include the control of pests and diseases, and other physiological research. Because the ordinary least squares (OLS) assumptions were met, the sum of the lag coefficients is an unbiased estimate of the total elasticity. The adjusted R-squared value shows that 87 percent of the variation in plum production can be explained by the changes in the independent variables. The Durbin-Watson statistic of 1.98 indicates that the model has a limited degree of positive autocorrelation. Recall that the price of fertilizer was used as a proxy for conversional inputs, which were found to have a significant effect on the industry's output: such that a one percent increase in the use of conventional inputs was found to result in a 0.87 percent increase in industry output. The model suggests that there is a positive relationship between the area planted and plum output. A one percent increase in the area planted will increase the industry output by 2.0976 percent.
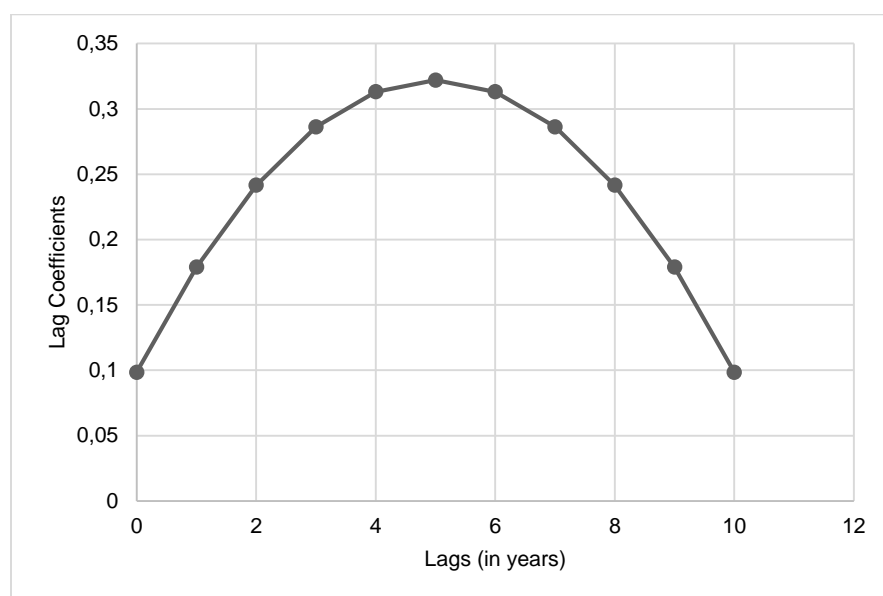

Figure 2: Lag structure of RD effects on plum output
Source: Authors own extraction from Eviews

The spread of the effects of Research and Development is illustrated by Figure 2 above. RD expenditures affect industry output positively in the same year as the investments and its benefits are felt over a period of ten years, with the maximum benefit experienced in the fifth year after the research investment after which it declines. This decline relates to

the expenditure in year zero.

In order to convert the output quantity into output value, the elasticities were converted into value of marginal products. After discounting the benefits to allow for the long lag between the outlays and results, this gave a marginal internal rate of return of 14.23 percent. This figure suggests that for every $100 increase in R&D investment, industry output increases by $14.23.

Conclusion

The estimated marginal internal rate of return for plum R&D investment in South Africa is 14.23 percent. The results of this study imply that research and development efforts for plums were beneficial. In this paper, it is shown that investing in profitable technologies can improve agricultural productivity. Given the nature of the industry and the benefits from research, it makes economic sense for both the beneficiaries and government to be funding the R&D efforts.

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