PRIVATISING AGRICULTURAL R&D, AN EXAMPLE FROM THE SOUTH AFRICAN SUGAR INDUSTRY

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Abstract

Given demands on public funding, the question arises whether agricultural research should be the responsibility of the public or private sectors, or whether the state should play a facilitating role. These issues are studied using the management and success of R&D in the South African Sugar Industry as an example. The usual answer is that research should be publicly funded if it is a public good and privately funded if a private good. It is shown that even if aspects of research have clear public good characteristics, then it is still possible to internalise externalities. Sugar cane farmers pay a levy of about 1.0% of the value of the crop to finance their R&D package, which includes research, training and extension. The sugar growers decide on the amount of the levy themselves. A possible reason why sugar farmers agree to this levy is that a bottom-up multidisciplinary research programme is followed in which they have a direct say. Scientists from different disciplines work together on a single crop. The South African government should consider the Dutch example where the role of government has shifted from administrator of institutions to stimulator (sponsor) of research. Government should thus still play a critical role in R&D funding in South Africa and there is concern that State funding has declined. Private incentives for research may be weaker in the case of generic research with broad applications across commodities. However, in the latter case it will be expected that different commodity organisations will embark on joint projects as has happened in the past.

1. INTRODUCTION

The majority of people in South Africa are poor. The production of safe and nutritious food at affordable prices is therefore a national objective. Investment in agricultural research and development (R&D) is consequently essential in order to improve agriculture's productive capacity. However, with severe demands on public funding, the question arises whether agricultural research should be the responsibility of the public or private sectors, or whether the state should play a facilitating role.

Whether research can be privatised raises issues such as public versus private goods, spillovers and welfare redistributional aspects. For instance, will the

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private sector under-invest in agricultural R&D? Even if aspects of research have clear public good characteristics, then it is still possible to internalise externalities. These issues are studied using the management and success of R&D in the South African Sugar Industry as an example. In this Industry, R&D is financed through levies. The desirability of extending this research programme to other agricultural industries is explored.

2. THEORETICAL CONSIDERATIONS

2.1 Public goods, private goods and R&D

Public goods are characterised by two criteria, namely nonrivalness and nonexcludability. Nonrivalness means that the satisfaction one consumer receives from a good, does not detract from the enjoyment derived by others. The use of agricultural R&D by one farmer does not preclude others from benefiting from it. Agricultural research thus generally meets the nonrivalness criterion.

Nonexcludability states that if a public good is provided to one individual, additional consumers cannot be excluded from the benefit of the good through fees (Pasour, 1990). The extent to which exclusion is feasible depends partly on whether it is a basic science, applied science or the development of technology and its concurrent extension to users. Basic research is often published in scientific journals accessible to everyone. Aspects of basic research can be characterised as a public good if both above-mentioned criteria are being met. In the Netherlands, UK and USA, government funded agricultural R&D has been redirected towards a heavier emphasis on basic research (Alston *et al*, 1999:278).

Investment in public goods may be sub optimum, due to spillovers, as the benefits are captured by others rather than the innovator and therefore private research may be under funded (Ruttan, 1982). However, Pasour (1990) questions the spillover rationale arguing that spillovers often arise in the economy, which does not imply a role for government. This public good rationale is less valid as one moves from the basic sciences to the development of new technology. Developers of new technology in agriculture can often capture returns from their investments through copyrights, patents and fees. A new plant variety or machine can be patented, printed information can be copyrighted, admission fees can be charged for information etc.

If research does not meet both criteria, then there is no reason why private investment will be sub-optimum. In areas where the private sector is involved such as developing new varieties, the competition from the public sector may be seen as unfair.

Thirtle and Echeverría (1994) suggest that the level of public intervention depends on the type of research and that few research activities can be classified as purely public or purely private. This implies that the split between public and private research has several dimensions and that efficient institutional arrangements will be specific to a particular activity. Technical innovations, such as in the field of biotechnology, may move the boundary towards increased private activity, but public and private contributions should be viewed as complementary rather than substitutes (Thirtle & Echeverría, 1994).

Persley (1998:283) states that public sector R&D is decreasing worldwide and that it is partially offset by increasing private sector investments. Private sector investments have continued to grow and have surpassed public sector investments for developed nations (Huffman & Just, 1999). In general, private sector investment in the developed world is estimated to account for half of the agricultural research expenditures (James, 2002). For developing countries, private sector investments are generally lower than public sector investments and although growing, account for only 10-15% of total agricultural R&D expenditures (World Bank, 2002). The low level of agricultural R&D expenditure by the private sector in developing countries infers scope for increased investment. Recent data show that private sector investments in agricultural R&D in some developing countries are increasing faster than public sector investments. This trend is stimulated by the introduction of policies to encourage increased private sector participation by the most advanced developing countries (James, 1996). Alston *et al* (1999:276) state that public funding has shifted away from traditional productivity enhancing research areas toward new research agendas such as environment, natural resources, human nutrition and food safety.

2.2 Externalities and research

Private provision of R&D may be sub-optimum if the gain from research is captured by others. As technological advances have lowered food prices consumers are major beneficiaries and free riders. However, government provision of research may create forced riders.

The theory of bureaucracy holds that there is a tendency for public sector services to be over supplied. The reasons are the separation of power and information (information problem) and separation of power and responsibility (incentive problem). The government agricultural research organisation cannot acquire information on individual preferences and production opportunities to determine research expenditure in the public interest (information problem). Furthermore, expected profits and losses do not provide the driving force for investment in a government department R&D unit (incentive problem).

2.3 Beneficiaries and welfare redistribution

Consumers are main beneficiaries as increased productivity translates into lower consumer prices. How consumers are affected depends upon the product in question. In the case of export products, additional production leads to greater exports and the landowners are main beneficiaries. However, consumers may still benefit even if the product is exported. Agricultural import prices for many export products are higher than domestic prices, for instance fruit and maize, due to distant destinations and high transport cost. Exceptions are sugar (from Swaziland), meat, wheat etc. In the case of maize, the import landed price exceeds the local domestic price. Maize research thus benefits local consumers of maize as well as consumers of livestock products such as broilers. Maize p.c. consumption of low income groups is higher than for other groups and the very poor benefit from increased maize production, provided markets are free to translate increased production into lower prices.

In the case of export fruit crops, an increase in local production through technology may lead to an increase in local sales and lower local prices, as an almost fixed percentage of local crops do not meet export requirements (Gay & Nieuwoudt, 2000). South African consumers are thus major beneficiaries of R&D in the fruit sector. Labour may benefit relatively less as economic theory suggests that the demand for labour in both subsistence and commercial agriculture is elastic in Southern Africa (Nieuwoudt & Vink, 1989). The supply elasticity of land is inelastic and this input captures the rent. The supply of labour in South Africa is expected to be elastic due to high rural unemployment and unspecialised nature of unskilled labour. An increase in demand for labour as a result of technological innovations is thus not expected to increase wages, but it may lead to higher employment. Higher yields will increase the demand for all inputs such as labour and machinery. Different areas differ and in the labour intensive fruit growing areas of the Cape, labour may be more of a constraint.

Research may have welfare implications on the following groups:

- consumers versus producers;
- small versus large scale farmers;
- early versus late adopters of research;
- poor versus wealthy consumers;
- land owners versus labour, etc; and
- importers versus exporters.

Some technology is more appropriate to large than small-scale farmers such as certain mechanical operations. Other types of technology benefit both, such as

hybrid seed. Early adopters benefit as profits of innovators increase. After the innovation is widely adopted, product prices may decline. It is possible that larger farmers are the earlier adopters, as they may have a greater incentive to adopt technologies (benefits a larger output) than small-scale part time farmers.

Food consumption p.c. for different products differs amongst population groups. For instance, consumption p.c. of dairy products, eggs, pig meat and fruit is high for high income groups, while p.c. consumption of maize (white) is high for low income groups. Some products are consumed by the wealthier and some more by the poor.

Some innovations may be labour replacing, such as some chemicals and mechanical innovations. The benefits and welfare redistribution of agricultural R&D must be seen in terms of the shadow prices of benefits (import price if commodity is imported and export price if exported). Welfare redistributional impacts of technologies are complex as some groups may be affected in an indirect way.

2.4 Theoretical and practical advantages/disadvantages of public/private research

Arrow (1962) contends that the private sector under-invest for three reasons: inappropriability (public good argument), uncertainty (investors are risk averse) and indivisibility (high fixed cost). In reply to Arrow (1962), Demsetz (1969) argued that the market failure situation is a necessary but not sufficient condition for government intervention. Government failure may be more of a problem than 'market failure'. Examples of the latter are the over-staffing of public institutions and the inability of public institutions to hold qualified staff due to lack of incentives. Further, linkages between researchers and farmers are weak while researchers are not responsive to clients' needs (Demsetz, 1969). However, the potential of market failure as a consequence of underinvestment in research, relative to the socially optimal level, is an important justification for public agricultural research in issues with limited incentive for the private sector (Sonka & Pueppke, 2002). It may be argued that if research becomes too demand-oriented, that the research agenda may neglect broader societal and environmental issues (Tabor *et al*, 1998:140).

2.5 Public and Private Sector Roles

The roles of private and public sectors in agricultural research differ with respect to objectives, areas of research and types of technology.

2.5.1 Differences in objectives

The private sector, driven by a profit motive, may under-invest in development projects such as poverty alleviation. The question is thus (a) what can the private sector do better or as well as the public sector and (b) what can the private sector be encouraged to do.

2.5.2 Area of research and type of technology

Research is a continuum process of activities with basic scientific research at one end followed by applied research with product development at the other end. The boundary between private/public research depends not only on the basic or applied nature of the research, but also on the research area, as mechanical innovations are usually more privately undertaken than biological R&D.

The role of private and public sectors vary between technological areas as they differ in patent enforceability, economic life and the ability of rivals to imitate (Rauser *et al*, 1981). Thirtle and Echeverría (1994) suggest that basic agronomic R&D falls in the public category, while product development of mechanical innovations should be left to the private sector.

2.5.2.1 Mechanical technology

Gains from innovations are embodied in technology and benefits are derived from the sale of machines. Patents are fairly straightforward for machinery technology and R&D can often be left to the private sector (Thirtle & Echeverría, 1994).

2.5.2.2 Chemical technology

As in the case of machinery technology, the private sector dominates, although public intervention is necessary with regulatory procedures (Thirtle & Echeverría, 1994).

2.5.2.3 Biological technology

Patenting is more difficult than with mechanical and chemical technology. Some crops such as wheat, millet, cowpeas and groundnuts can reproduce themselves with little genetic variation and it is thus not profitable for private seed companies to invest in the breeding, production and marketing of varietal crops, because farmers do not have to purchase seed every year to maintain genetic purity (Rusike, 1995). By contrast, maize hybrid seed must be purchased every year, the parent lines can be kept secret and R&D investment can be recovered from royalties. In the USA the public sector tends to produce plant breeding material, while the private sector develops the final product (Evenson, 1982 as reported in Thirtle & Echeverría, 1994).

2.5.2.4 Managerial (agronomic) technology

Agronomic research includes dates of planting, planting density, spray regimes and weeding densities. Ownership is difficult to establish, which limits private sector activity.

2.5.2.5 Economic research

Economic research on institutions, such as private/communal tenure is a public activity, compared to activities with a clear private gain.

Private sector incentives to undertake research will be weak where: (a) the lag between R&D investment and returns is long; (b) generic research with broad application across commodities and where institutions to protect property rights are ineffective; (c) the main product of the research is information; and (d) the potential market size is limited (World Bank, 2002).

In conclusion, the aim should fall on complementarity of research efforts of the public and private sectors (Huffman, 2001). In other words, the public sector must not compete with private sector efforts.

3. R&D IN THE SOUTH AFRICAN SUGAR INDUSTRY: A HISTORICAL PERSPECTIVE

An Overseas Development Agency study (ODA, 1994) concluded that the agricultural research system in South Africa is probably the best equipped and most fundamental one in Africa. In the present study, the focus is not so much on the quality of R&D in South Africa, but more on the question of privatisation using the Sugar Industry as an example.

3.1 Management of R&D in the sugar industry

When the Sugar Cane Experiment Station was established in 1925, the opinion was that it is unsatisfactory to have scientists, however eminent, working on a number of crops and conversely, that it is necessary to have a number of scientists, of different disciplines, working on a single crop (Donovan, 1986). A multi-disciplinary approach was thus followed, in the sense that scientists from different disciplines focussed on a single objective. Research was expected to yield real dividends and basic research was not pursued.

Early work concentrated on varieties, diseases, pests, fertilisers, soils and factory processes and control. The Advisory Service was added in the fifties. More than a third of all growers use the Fertiliser Advisory Service started in 1951, and more than 30,000 soil samples are tested every year. Since the mid-eighties direct

payment was introduced for certain services. A user charge was introduced by the Fertiliser Advisory Service for training courses and certain farm planning services.

3.2 Research activities

The Experiment Station was initially established to screen and release new varieties and today that is still a major function of the Station. The variety programme has released more than 20 varieties for commercial production. Present policy is to breed varieties that are suitable for particular areas within the industry and which, therefore, are adapted to local conditions.

The Station also conducts research into various facets of cane growing including: (a) the use of herbicides, pesticides and other agricultural chemicals; (b) the development and testing of agricultural machinery and equipment; (c) irrigation, drainage and water management; (d) nutritional requirements of sugar cane; and (e) the study and monitoring of pests and diseases.

In addition to doing research, the Station offers the following services to growers: (a) training of farm workers; (b) analysis of soil and leaf samples and making fertiliser recommendations; and (c) courses on various aspects of cane production.

The link between experimentation and commercial production of sugar cane is provided by extension officers. Growers can approach the extension officer for general advice or consult specialists at the Station on particular problems.

The Station has the following departments: Agricultural Engineering, Agronomy, Biotechnology, Chemistry and Soils, Entomology, Farm Planning, Pathology, Plant Breeding, Special Projects, Extension, Biometry, Data Analysis, Human Resources and Training.

A major function of the Station is the release of new cane varieties. Patenting of biological material is difficult as plants reproduce themselves with no genetic variation and farmers do not need to purchase new planting material every year. It is thus difficult to enforce patents of varieties as copying is easy and the farmer can multiply his own plant breeding material. The present policy of breeding varieties suitable for areas may limit potential private sector activities.

The area of research at the Station is Managerial (agronomic technology), relevant to local circumstances, which is more of a public nature, although the type of research is more product development than basic. The area and type of research in the relatively minor department of agricultural engineering, appear more conducive to private enterprise.

The fact that the Sugar Industry is conducting R&D of a public goods nature, is because spillovers from research are internalised within the industry. Therefore, it does not really matter if patent rights on new sugar cane cultivars cannot be enforced, as all farmers benefit. The public good/private good distribution of R&D is thus only helpful in showing that the government should not conduct research on private goods (where copyrights can be enforced, etc). Commodity organisations still have the incentive to conduct research on a wide range of public goods (where copyrights cannot be enforced) as long as the group of farmers producing the commodity benefit. The question is then more whether the commodity is sold in the market and whether a levy can be charged on sales.

4. CAN EXPERIENCE AND INFORMATION BE TRANSFERRED TO OTHER INDUSTRIES?

Few research activities in South Africa are undertaken under completely free market activities. Examples of the latter are the seed industry in South Africa. The South African Seed Industry is well developed and makes a major contribution to technology transfer. The return on an investment in the seed industry can be captured through patents and these goods are thus of a private nature. Even if R&D is of a public goods nature, then it still does not imply that the government should undertake it. In the latter case, research can be undertaken by commodity organisations, as for the sugar industry. Research could be funded by a levy imposed on producers. Consumers benefit in instances where investment in R&D leads to lower commodity prices and the tax payer may be required to make a contribution to agricultural R&D in such cases. Consumers also benefit from improved quality, food safety, etc.

This does not imply that the government should actually do the research. The government can contract research out, or share in the cost of private commodity organisations. The latter development has taken place in the Netherlands (Dutch Ministry of Agriculture, 1996). The Dutch government has become more of a client or sponsor, paying for programmes or products, while research institutions are being put at a distance from government. In the past, this government was held responsible for developments, which were desired by society. Now the government confers these responsibilities as much as possible to those who have an interest in these developments (Dutch Ministry of Agriculture, 1996). The role of the government is shifting from administrator of institutions to stimulator of developments, which means that funding is earmarked for policy priorities. The Dutch R&D is also shifting away from research regarding agricultural production and focussing more on environmental issues.

There are advantages in shifting research away from the government towards

commodity organisations, while the government sector is faced with several problems such as not responsive to clients' needs, which is an example of a government failure problem (Demsetz, 1969). Changes since 1997 to National Science and Technology Policy in South Africa has been designed to introduce a greater degree of competitiveness and responsiveness to stakeholder needs.

4.1 Management of R&D

According to Donovan (1995a), in spite of the transfer of agricultural research from the government to the ARC, funding remains almost entirely with the government, with top-down decision making. According to an anonymous reviewer this situation changed significantly since the introduction of a competitive parliamentary grant system in 1997. Private funding for the ARC reached 48% of total expenditure in 2001/2002 while some ARC grain institutes receive over 64% of their funding from industry and private sources. This reviewer is of the opinion that decision making is not top down as the client determines what he wants to pay for. Faculties of agriculture at universities have traditionally conducted research on problems of commercial agriculture almost exclusively for higher degree purposes. Universities, however, lack extension staff for the transfer of information. In a commodity research programme, a bottom-up approach is used. In the South African Sugar Industry the policy, funding and management of sugar cane R&D are exclusively in the hands of the stake holders, the cane growers.

4.2 Funding

The South African sugar growers pay a levy of about 1.0% of the value of the crop to financially support their R&D package, which includes extension and training (Sugden, 2002). The growers themselves decide on the levy (Donovan, 1995a). A commodity organisation may not have a critical mass to undertake R&D. However, if the gross output of a commodity is too small to support R&D then commodities may be grouped. For levy funding to present an effective use of resources, it is preferable that the commodity passes through a narrow marketing channel, keeping collection costs to a minimum (Alston *et al*, 1998). Worldwide, only a small proportion of total R&D resources are generated through levy funding, in spite of the fact that financing can be made more efficient, in terms of a more efficient total quantity of research resources, a lower cost of raising revenues and greater allocative efficiency by using more industry levy funds.

Evenson (1984) estimated research investment as percentage of value for 18 crops. The top seven crops in his study had research expenditure less than 0.5% of value and were grown on a commercial scale.

4.3 Organisational structure

The top-down decision making of R&D devoted to the commercial agricultural sector in South Africa is seldom appropriate under developing country conditions. Also, since research and extension are institutionally separated, different objectives and priorities are pursued (Donovan, 1995b).

The problem of top-down decision-making can be solved by empowering the stakeholders, while the problem of inappropriate technology and its ineffective transfer can be solved having research and extension integrated by a common mission in the same R&D organisation. This can be achieved in a commodity (producer) R&D organisation, such as the South African Sugar Experiment Station.

The needs and requirements of farmers in the developing sector are very different from large-scale commercial farmers. In the small-scale subsistence agriculture, problems are complex and interrelated. The organisational structure must depend on the needs of the stakeholders it serves. It is thus necessary to know the kind of farmers it is to serve and to derive a mission statement from these.

In South Africa there are about 62,000 commercial farmers and 1.27 million non-commercial producers (Bembridge, 1988). In the non-commercial sector, income derived from agriculture represents only about 10% of total farm income (Nieuwoudt & Vink, 1989), which includes wage remittances, pensions etc.

In the developing agricultural sector the priority need is infrastructural development, the provision of water, roads, housing, etc. which could provide employment opportunities. Williams *et al*, as quoted by De Lange (1990), indicate that only about 20% of rural households show real interest in agriculture. These subsistence farmers are deficit producers (buy more food than they sell). Therefore a levy to fund R&D cannot be imposed on sales. The task of policy makers in South Africa is to maintain productivity of the commercial sector, develop the potential of emerging farmers while sustaining the welfare of people on land with low potential.

4.4 Stakeholders in R&D

A single organisation such as the ARC will experience a conflict of interest if it caters for the needs of commercial and non-commercial farmers. With a constrained budget, it may be inclined to give preference to fee paying stakeholders rather than resource poor farmers. According to Donovan (1995b), if the ARC were unbundled, few of its functions would remain funded and

controlled by government and many could and should be privatised. The theory of bureaucracy holds that a government R&D organisation suffers from two weaknesses, an incentive problem and an information problem. The incentive problem is a result of the fact that expected profits and losses do not provide the driving force for investment in a government R&D department.

A government department or parastatal is a public institution and, therefore, political. In this regard, operations will be judged ultimately by politicians and not by impersonal market forces. Their political nature means that they will be seen to meet a variety of objectives, confounding their success. The information problem holds that a state research institution cannot acquire the information on individual preferences and production opportunities to determine the overall level or the pattern of R&D expenditure that would be of optimal public interest. Thus, because of limits on information, even the most selfless research or extension decision maker must choose some feasible, albeit lower-level goal, such as budget maximisation (Pasour, 1990). A government R&D Unit will thus follow a top-down approach rather than a bottom-up approach and will tend to be supply driven rather than demand driven.

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

Whether agricultural R&D is a private or public good depends upon whether developers of new technology can capture returns from investments through copyrights, patents or fees. If the latter is possible then R&D is a private good and government R&D is unwarranted and unfairly competes with commercial interests.

Even if patents or fees are not possible (R&D a public good), then research may be undertaken by commodity organisations, such as in the South African Sugar Industry. The externalities arising from research are internalised within the organisation. Private incentives for research may be weaker in the case of generic research with broad applications across commodities. However, in the latter case

it will be expected that different commodity organisations will embark on joint projects as has happened in the past. In the case of basic research, which is often published in scientific journals accessible to everyone, private funding may be insufficient and a role is seen for the government.

The issue is what can the private sector (seed company, commodity organisation) do better, or as well as the public sector and what can the private sector be encouraged to do. Sugar cane farmers pay a levy of about 1.0% of the value of the crop to finance their R&D package, which includes research, training and extension. The sugar growers decide on the amount of the levy themselves and it is not imposed on them from outside. A possible reason why sugar farmers agree to this levy is that a bottom-up research programme is followed in the sense that they have a direct say in how the money should be spent.

It is proposed that commodity organisations in South Africa should take more control of management and funding of their research which appears to be the case. The South African government should further follow the Dutch example where the role of government has shifted from administrator of institutions to stimulator (sponsor) of research. The South African Government should thus still play a critical role in R&D funding in South Africa and there is concern that State funding has declined (Liebenberg & Kirsten, 2003).

In a move towards privatisation, a bottom-up research approach is recommended where institutes are autonomous and only responsible to their stakeholders. The South African Sugar Cane Experiment Station has adopted a Systems Analysis Approach to research, since the Station was established, in the sense that scientists from different disciplines (agronomy, soil science, plant breeding, extension etc.) work together on a single crop. More than a third of growers use the Fertiliser Advisory Service and during the past decade the Station analysed more than 30,000 soil samples per annum.

REFERENCES

ALSTON JM, PARDEY PG & ROSEBOOM J (1998). Financing agricultural research: International investment patterns and policy perspectives. *World Development* 26(6):1057-1071.

ALSTON JM, PARDEY PG & SMITH VH (1999). *Paying for agricultural productivity*. John Hopkins University Press, Baltimore.

ARROW KJ (1962). *Economic welfare and the allocation of resources for invention. The rate and direction of inventive activity*. Princeton University Press, Princeton, pp 609-625.

BEMBRIDGE TJ (1988). Considerations in technology transfer in less developed areas of Southern Africa. *Development Southern Africa* 5(2):212-226.

DE LANGE AO (1990). *A Paradigm for rural development*. ADRI, Newsletter, September 1990. University of Fort Hare, Alice.

DEMSETZ H (1969). Information and efficiency: Another viewpoint. *Journal of Law and Economics* 12:1-22.

DONOVAN PA (1986). *Management of agricultural research and development with particular reference to the Sugar Association Experiment Station*. Unpublished MAgric Mgt Thesis, University of Natal, Pietermaritzburg.

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

DONOVAN PA (1995a). The management, funding and organisational structure of agricultural R&D in Zimbabwe, Malawi and South Africa. Part 1. Management and funding. *Agricultural Systems* 47:259-271.

DONOVAN PA (1995b). The management, funding and organisational structure of agricultural R&D in Zimbabwe, Malawi and South Africa. Part 11. Organisational structure. *Agricultural Systems* 47:273-290.

DUTCH MINISTRY OF AGRICULTURE (1996). *Knowledge policy plan, 1995-1998*. 's-Gravenhage, The Netherlands.

EVENSON RE (1984). *Benefit and obstacles in developing appropriate technology*. In: Eicher CK & Staatz J (ed), Agricultural Development World, John Hopkins University, Baltimore.

GAY SH & NIEUWOUDT WL (2000). Influences of a free trade agreement between South Africa and the European Union for fresh oranges. *South African Journal of Economic and Management Sciences* 3(3):484-498.

HUFFMAN WE (2001). Public-private R&D relationships: Discussion. *American Journal of Agricultural Economics* 83(3):754-757.

HUFFMAN WE & JUST RE (1999). The organisation of agricultural research in western developed countries. *Agricultural Economics* 21(1):1-18.

JAMES C (1996). *Agricultural/R&D: The need for public-private sector partnerships*. Issues in Agriculture. Consultative Group on International Agricultural Research, World Bank, December.

JAMES C (2002). *Progressing public-private sector partnerships in international agricultural R&D*. International service for the acquisition of agribiotech applications (ISAAA). http://www.isaaa.org/publications/briefs/Brief 4.htm. (Accessed 14 May.)

LIEBENBERG F & KIRSTEN J (2003). *Status of agricultural research and development policy in South Africa*. In: Nieuwoudt L & Groenewald J (eds), The Challenge of Change, University of Natal Press, Pietermaritzburg.

NIEUWOUDT WL & VINK N (1989). The effects of increased earnings from traditional agriculture in Southern Africa. *South African Journal of Economics* 57(3), 257-269.

OVERSEAS DEVELOPMENT AGENCY (ODA) (1994). *Restructuring agricultural research in South Africa*. Prepared by Corbett DCM, Lipton MG & Coulter JK for the Overseas Development Agency under British Aid arrangement.

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

PERSLEY GJ (1998). *Investment strategies for agriculture and natural resources*. CABI Publishing, New York.

RAUSER GC, DE JANVRY A, SCHMITZ A & ZILBERMAN D (1981). *Principal issues in the evaluation of public research in agriculture*. Agricultural Experiment Station Miscellenious Publication 8, Agricultural Station, University of Minnesota, pp 262-282.

RUSIKE J (1995). *An institutional analysis of the maize seed industry in Southern Africa*. PhD Dissertation, Department of Agricultural Economics, Michigan State University.

RUTTAN VW (1982). *Agricultural research policy*. Minneapolis: University of Minnesota Press.

SONKA S & PUEPPKE S (2002). Exploring the public's role in agricultural biotechnology research. http://www.agbioforum.org/vol2no1/sonka.html. (Accessed 14 May.)

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

TABOR SR, JANSSEN W & BRUNEAU H (1998). *Financing agricultural research: A sourcebook: International Service for National Agricultural Research (ISNAR)*. http://www.isnar.cgiar.org/publications/books/FSB.htm. (Accessed April.)

THIRTLE C & ECHEVERRÍA RG (1994). Privatisation and the roles of public and private institutions in agricultural research in Sub-Saharan Africa. *Food Policy* 19(1):31-44.

WORLD BANK (2002). Private sector research and user financing. http://www.worldbank.org. (Accessed 13 May.)