ISNAR WORKING PAPER No

POTENTIAL COMPLEMENTARITIES BETWEEN PUBLIC AND PRIVATE SECTOR AGRICULTURAL RESEARCH

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At the time of preparing this paper the author was a Research Officer at ISNAR; currently an Economist at the Agricultural Division of the Interamerican Development Bank. The views expressed in this document are those of the author and do not represent those of the institutions mentioned. This paper is based on several earlier documents for which the author acknowledges comments received from numerous individuals, particularly from Howard Elliott and Phil Pardey of ISNAR.

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Foreword

The worldwide trend towards privatization, coupled with Government budget cuts in many developing countries, is redefining the boundaries between public and private agricultural research. Private-sector research - conducted or funded by multinational and domestic agricultural-input companies, plantations, commodity institutes, foundations and farmers' cooperatives - grew substantially during the 1980s.

ISNAR has received several requests from public-sector research institutes to provide advice on how to define potential research roles among the several public- and private-sector elements of a national agricultural research system. This demand will certainly increase in the near future given the expected expansion of private activities and the budgetary restrictions facing many public research institutes. By understanding the roles and potential complementarities of public and private-sector research organizations, ISNAR will reinforce its assistance to public research organizations in developing countries in policy formulation, structure, and organization of national agricultural research systems.

The analysis of the relationships between the public and the private sectors in agricultural research is an ongoing ISNAR activity. In the early 1980s, ISNAR conducted a pioneering study describing the links between social organizations and technological change in Latin America and the Caribbean. This paper builds on this previous work and lays the ground work for follow-up studies on public and private-sector research interactions with the objective of improving the ability of policy makers to better understand and to more confidently make informed decisions about the relative roles of the public and the private sector in agricultural research.

Howard Elliott
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Abstract

Most of the literature on technical change in agriculture has focused on public-sector research although agricultural technology is not produced only by government research institutes. Private-sector organizations, play an important role in generating and transferring new technologies. The distinction between public and private sector research is not clear-cut. There is a complex, almost a continuum, of organizations conducting and/or funding agricultural research, which extends from government research institutes to private input and processing companies. An organization may be classified as public or private according to: ownership and control, sources of funds, and economic behavior. The type of private organization that predominate in conducting and/or funding agricultural research varies considerably among countries. Private research is located primarily in Latin America and Asia, and it is concentrated in a few large countries such as Brazil, Mexico, Argentina, and India.

The boundary between the public and private sectors vary according to area of research, the type of technology, the level of development and other factors. That is basic, strategic, applied and adaptive research; and managerial, biological, chemical and mechanical technology. Privatization needs to be regarded in relation to certain types of research activities, specific technologies, as well as the public and/or private nature of the organization, and not as a panacea. All else being equal, the private-sector should be relatively larger where: there is open trade that fosters commercialization, and commercial development has not been stifled by regulation; the cultural endowments were amicable to the creation of institutions that encouraged commerce; and there has not been opposition to the market on ideological grounds. Institutional changes, that may take time, will be necessary for the evolution of a better balance between public and private activities. Public intervention in agricultural research is necessary in cases where markets fail. The private-sector will underinvest in research because of inappropriability, uncertainty and indivisibilites. In addition there is a range of further reasons for public intervention: preserving competition, complementarity with education, public goods, discounting the future, unemployed resources, intervention on distributional grounds, institutional innovation, support of policies and imperfect knowledge. There are cases that research must be conducted or supported by the public sector or it will not get done at all, that is it must cover the basic end of the research continuum and if it should fail to do so, there will be no downstream private research and hence no productivity growth. There are also arguments against public intervention, since market failure is a necessary but not a sufficient condition for government intervention.

Three groups of factors influence the nature and the level of private agricultural research investments: (a) market factors, such as the expected growth in demand for agricultural products, derived demand for modern agricultural inputs, and factor prices facing farmers and agribusiness; (b) the ability of firms to appropriate the benefits from new technology; and (c) the technological opportunities for producing profitable products. The interaction between private- and public-sector research could take place through formal and informal channels. The structure and efficiency of the public-private interaction is affected by the amount and type of public and private research being conducted as well as by how much government policies and regulations impede (or discriminate) or encourage private-sector participation. Governments have a number of policy instruments with which to influence private research. Public-sector research can foster private-sector research by providing (or selling) research results and by training the personnel needed by private companies to conduct research. The development of intellectual property rights such as patents and plant variety protection laws, if they are well designed and enforced, can create the necessary incentives for private companies to invest in research.

In the short term for the more-developed countries and in the medium term for the less-developed countries there is likely to be an accelerating trend toward privatizing agricultural research. Moreover, the nature of the technologies being developed in the public and private domain is also likely to undergo substantial change. Taken together, these changes will reshape the conduct of agricultural research in less-developed countries, the relationship between less- and more-developed country (public and private) research activities, and the policy agenda facing public agricultural research institutions.

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1. INTRODUCTION

The institutional environment in which agricultural research is conducted is changing rapidly. The role of market forces and the reduction of government intervention has received considerable attention in recent years, especially in the more-developed countries. Although the main focus of privatization in less-developed countries has been on the industrial sector, attention has also been given to reducing the role of government in agriculture. The main targets for privatization have been public agencies supplying inputs and marketing outputs. This is important, for example, for the seed industry where plant breeding, seed multiplication, and distribution are often public-sector activities.

The worldwide trend towards privatization has also embraced agricultural research in the less-developed countries. During the last 20 years the involvement of private organizations in agricultural research has increased considerably. This is likely to precipitate substantial changes in the performance of agricultural research in the public sector. To benefit from the private sector's expanding role in conducting and/or funding research, public-sector research organizations will need to institutionalize arrangements to link efficiently with private efforts, ensuring complementarity and a rational division of labor. This means that an understanding of the roles of public and private research, national and international, and their potential complementarities becomes an important matter on the policy agenda for the 1990's.

New methods in biological research have also begun to change the research industry with new biotechnology companies conducting research and large chemical firms acquiring seed companies. Although most of these large firms have headquarters in the more-developed countries, they operate as transnational companies (directly or through subsidiaries) throughout the world. Whereas the economic impact of modern biotechnology research on agricultural production is not expected to be very significant at least for another decade, its implications for developing countries will be critical. Given this challenge, effective linkages between public and private research organizations (such as collaborative research programs and joint ventures) are called on to play a crucial role in establishing a sound research policy, which includes the implications of biotechnology.

Unfortunately, the contribution of the private sector has not been closely considered in most studies analyzing the role of research in agricultural development. The literature on technical change in agriculture has been concentrated on public-sector research, rather than on the totality of the research system. As a consequence, there are few quantitative data on how much private agricultural research is being conducted and still less information about its determinants or its impact on public research, farmers, and consumers. For example, with the exception of Griliches' (1957, 1958) studies, the private sector has until recently been largely ignored in the literature pertaining to technological change in production.[1] This lack of information may lead public research administrators to set priorities and allocate resources inefficiently. This is a major issue on the agricultural development agenda in the 1990s and it deserves further attention.

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[1] Despite the lack of studies focusing on private research in the past, the subject at last received some due attention in the 1980s. See Trigo and Piñeiro (1981), Ruttan (1982), Evenson (1983), Piñeiro (1985, 1986), Trigo (1988), Echeverría (1988, 1990a), and Pray and Echeverría (1988, 1989, 1991).

Some of the relevant questions associated with the public-private role in research are: in what instances does the private sector substitute for or complement public research? should governments encourage private involvement in research in high potential production areas while concentrating on the more difficult agro-ecological areas? what are the institutional arrangements that will increase the efficiency and effectiveness of the public-private interaction? i.e. what are the mechanisms for successful joint ventures, foundations, and other forms of interactions?

This study focus on how to improve agricultural research policy formulation and decision-making concerning the roles of public and private-sector agricultural research in developing countries. The objectives of this paper are to examine the relationships of the public- and private-sector in conducting and/or funding agricultural (technological, marketing and socioeconomic) research; and the interaction and potential complementarities of both sectors with respect to setting research priorities, financing, and implementation of research. The paper discusses how the changing roles of the several components of an agricultural research system can affect the organization, priorities, and programs of national institutes. It attempts to characterize alternative institutional arrangements concerning collaboration between public and private sector research organizations.

The main postulate of this paper is that a framework to understand the potential roles of public and private-sector organizations in conducting and/or funding agricultural research can be established based on the combination of three elements, the type of research being conducted or funded, the nature of the technology to be developed and the type of public and/or private-sector organization involved.

This is a working paper based on preliminary information; some of the ideas presented here are hypotheses and represent only the first step into a more thorough examination of the above mentioned issues. Most of these ideas have been presented and/or discussed in several documents and workshops.[2] It is anticipated that a series of studies will be carried out that follow up on some of these ideas in order to better understand the public-private roles and interactions as well as to quantify the scope and nature of private-sector research activities in less-developed countries.

This paper consists of three main sections. The public- and private-sector components of a national agricultural research system are defined in Section 2. The third section examines potential public- and private-sector research roles based on objectives, the nature of the technology to be developed and the type of research being conducted and/or funded. Special attention is given to the justifications for public intervention. Section 4 focuses on the determinants of private-sector investments in agricultural research and the scope of these activities by examining a tentative list of multinational and national companies involved in agricultural research in less-developed countries. In addition, this section discusses possible institutional arrangements between the public and the private sector.

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[2] Particularly in two studies that the author has been involved with, i.e. Chapter 10 in Pardey et al. (1991) prepared with Carl Pray, and an ISNAR report to the Africa Bureau of USAID prepared with Colin Thirtle.

2. DEFINING PUBLIC- AND PRIVATE-SECTOR RESEARCH ORGANIZATIONS

The distinction between the public and private-sectors, like the distinction between public and private goods, is not clear-cut. Table 1 lists some of the organizations involved in agricultural research in both sectors. Within the private sector a difference is made between non-commercial and commercially oriented research organizations. This last category is, in turn, subdivided into farm, input and food sectors.

Table 1. A typology of organizations that conduct and/or fund agricultural research

PUBLIC SECTOR	National institutes of agricultural research Departments of ministeries of agriculture, livestock, education, and science and technology National councils Parastatals National science and research foundations Agricultural schools and universities Regional organizations and networks Regional agricultural research centers International agricultural research centers		
PRIVATE SECTOR	Non-Commercial	Agricultural schools and universities Foundations Non-governmental organizations Private-sector targeted aid agencies	
	Commercial	Farm sector	Farmers Cooperatives and producer associations Plantations, estates and other large firms Commodity institutes Technical assistance
		Input Companies	Seeds Feeds Animal health products Agro-chemicals Machinery and equipment
		Food sector	Food processing and other related companies

The distinction between public and private-sector research organizations portrayed in table 1 is arbitrary since there is a continuum of institutional arrangements, from a broadly based public research institute to a private company dealing with a single input. For instance, many organizations that play an important role in developing and transferring technology in less-developed countries, such as nongovernment organizations, cooperatives, foundations, and joint ventures (between public and private organizations, domestic and foreign) fall between these extremes. All these different entities constitute what this paper broadly refers to as the private sector.

An institution may be classified as public or private according to: (a) ownership and control, (b) sources of funds, and (c) economic behavior, particularly the need, or lack of need, to operate profitably. This allows institutions such as Ministries to be listed as public, but there are a wide range of possibilities. Universities and research institutes may be predominantly public, but there may be some element of private-sector input in both decision-making and funding, as well as pressures to operate with commercial aims in mind.

With the organizations classified as private in table 1, the scope for diversity is probably greater. For example, some farmers cooperatives would qualify as private under all three criteria listed, but others are controlled by political appointees, consistently operate at a loss and are hence reliant on public funds. Some input supply companies, processing organizations and plantations are private, others public and some a mixture of the two. For example, although the Kenya Seed Company would be regarded as private, the government is the majority shareholder.

Similarly, many non-governmental organizations would qualify as private under the first and third criteria, but may be recipients of public funds. Foundations are typically private in the ownership and control sense, but if the funding is sufficient, may be free of the need to operate at a profit, and so may behave like public sector institutions.

Commodity institutes vary, but may be viewed as part public, part private in terms of control, since they must serve the needs of their industry and although they are subject to commercial considerations, funding is frequently from a levy on producers, so they do not have to sell the products of their research. This type of collective invention is suited to an industry with many small producers, who stand to gain from research, but are too small to conduct it individually. By contrast, plantations are sometimes sufficiently large to be able to finance their own research. They also pay levies to Commodity Boards and may be prepared to pay for research conducted by the Board's research establishments, rather than performing it in-house. Even if they do not conduct research, they may play an important role in the diffusion of technology, since large firms, with access to non-farm resources and capital are best placed to take the risks inherent in innovation (Tiffin and Mortimore 1990). Thus, the existence of large estates may benefit smallholders.

The last point adds another possible criterion to the list for classifying public and private research. It is not difficult to find examples of research that is both performed and paid for by private bodies, who choose to make the results publicly available at no charge to groups such as small farmers. So, the classification system may need to include consideration as to whether the research output is to be in the public domain, or if it is to be private property. Similarly, as public-sector organizations in more-developed countries have been put under increasing pressure to behave like the private sector, universities and public research institutes have increasingly charged royalty fees for research output. Hence, we can no longer assume that there is a straightforward correspondence between the source of the innovation and the property rights applied to it.

A further distinction could be made between public and private domestic and foreign organizations, although location per se may not be an adequate criterion because country of source and country of use may well differ. Research targeted at a specific region may not be performed in the region, or the spillovers between jurisdictions may be great enough that

research conducted primarily for the country of origin may have considerable consequences for that region. Research carried out by multinational companies is international in nature. By transfering their technology to local subsidiaries or by exporting technology directly these organizations constitute foreign private sources of technology. International research centers are considered a foreign-public source of technology. Their relationship with private sector companies will also be examined.

A last taxonomic issue is the distinction that is often made between the generation of new technology by research and the transfer of existing technology (diffusion), both across regions within one country and across national boundaries, including from the more- to the less-developed countries. This paper concentrates on public-private interactions on the research side of the technology generation and diffusion process.

There are also important public-private interactions in the transfer of technology phase, particularly because private companies focus more on technology marketing than on technology generation.[3] There are many benefits and also limitations of private transfer of technology. Private marketing is usually effective because the technologies being transferred are economically suited to users needs. On the other hand private companies will not reach the poorer regions. However according to the stages involved in technology generation the transfer and marketing of a technology will often require adaptive research. Again the demarcation criterion between the public and the private sectors is not entirely adequate.

In sum, it is difficult to classify research as public or private as it is to draw a clear line between basic and applied research - again, there is a continuum - made more complicated by the fact that nominally public institutions may be de facto private in their behavior and private companies can behave in a non-commercial manner. The rest of this section examines in more detail the organizations listed in Table 1.

2.1 Public-sector research organizations

The public sector still plays a central role in agricultural research systems of less-developed countries. National research institutes are the most common public-sector sources of agricultural technology. In addition, and depending on the geographic region, departments of ministries, as well as schools of agriculture, university faculties of agriculture, and research councils are also important public-sector components of the agricultural research system.

The research done by these organizations can be directed to adapting technologies developed elsewhere or to creating new ones. International and regional agricultural research organizations,[4] as well as national agricultural research institutes in other countries are the main foreign, public sources of agricultural technology.

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[3] See Pray and Echeverría (1989) for an examination of the public and private sector roles in transferring technologies and on the linkages between research and technology transfer.

[4] Such as the CGIAR centers, and CATIE and CARDI in the Latin American and Caribbean region, respectively.

Most of the agricultural research literature focuses on public-sector research policy, organization, and management.[5] After more than fourty years of the creation of public research institutes and given the current trends towards modernizing agriculture, it is essential to consider new institutional models and the new complexities of the system that public organizations are part of. This section will concentrate on the non-public research organizations of an agricultural research system.

2.2 Private sector - non-commercial

Foundations. Research foundations are characterized by having boards of directors that are independent of government and by having funding that is neither from government nor raised from the commercial activity of the foundation (charitable endowments, for example). These organizations are common and quite effective in Latin America; most of them have been established with USAID support (Sarles 1990).

In addition, foundations such as Ford and Rockefeller have played a major role in agricultural research. These foundations are a source of funding for public sector bodies, such as the CGIAR and universities, but also compete for donor funding for their consultancy operations, which involve them more directly in the performance of research. Since foundations are usually free of the profitability constraints that face private commercial institutions, they may take part in any area of research.

Non-governmental organizations (NGOs). This organizational type covers a remarkably heterogeneous group of institutions. They vary in size from the sub-national to international, and in mode of operation; some implementing project or programs directly while others work through local NGOs. Grassroots organizations seeking to promote the welfare of members on a local scale through an agreed set of activities could also be considered as a subset of NGOs. The later share the philanthropic orientation of the former but tend to be more formally institutionalized and are not normally membership organizations.

Farrington and Biggs (1990) list three objectives of NGOs: (a) service provision, originally focusing on relief activities, but now more developmental; (b) organization building, working with local communities to identify problems and organize local efforts to solve them; and (c) support and advocate functions, which include lobbying and the provision of backup services, such as research and policy analysis, for other NGOs.

Although the role and importance of NGOs in agricultural research is not clear several researchers argue that NGOs have an advantage over government organizations in targeting their efforts at the poor and securing their participation as well as being more cost-effective and innovative (Copestake 1990). Their work with farmers is not encumbered by connections to bodies with any formal authority and they are not centralized or bureaucratic. Thus, the greater the diversity of the farming system, the greater the advantage their flexibility gives them over centralized authorities. Their role in on-farm research allows

[5] See, for example, Pardey et al. (1991) for the most recent work on public-sector related agricultural research policy, and Jain (1989) for a review of the organization and structure of public-sector agricultural research systems.

them to articulate the demands of resource-poor farmers. This plus the fact that they are usually biased towards local institution-building could be of use to public organizations and in some cases there is collaboration.

Aid agencies. The structure of international and national development agencies includes institutions that are intended to deal with the private sector in developing countries. These bodies are formally part of the public sector, yet they are the intermediaries between public-sector donors and private-sector recipients; they assist companies rather than governments. Such institutions vary a great deal. The World Bank's private sector loan institution is the International Finance Corporation. The UK's Commonwealth Development Corporation lends, but also operates extensively in developing countries, providing management and technical assistance. It is somewhat oriented towards agricultural technology, and although it is part of the UK aid program, it operates as a private company expecting to generate income from its investments. The Corporation has developed an expertise in agricultural research-related areas, such as seeds and plantation crops; it demonstrates that private commercial activity is viable. The role it has played in developing market institutions could probably be replicated.

2.3 Private sector - commercially oriented

Private-sector commercially oriented research is conducted by agricultural production (farm sector), input, and processing (food sector) industries. The agricultural production industry, i.e. farms and plantations, develops technology to reduce costs and to increase the demand for its products. The agricultural input industry produces technologies that are intended to increase farmers' productivity. Agricultural processing industries develop technology for farmers so that the product purchased by the industry will be cheaper or of better quality. Within these industries, research is conducted mainly by two types of private organizations: individual companies and groups of firms or farmers.

2.3.1 Farm-sector organizations

Farmers. Because the farm sector is composed of a large number of small producers and since there are economies of scale in research, farmers will not conduct research themselves. Farmers participate in screening and adaptation of technologies before adoption takes place.[6] The notion of farmers as passive recipients of technology produced by others has been increasingly questioned and it is now widely accepted that farmers are innovators in their own right. For instance, farmers' innovations in machinery improvement and animal breeding have been noted.

Cooperatives and producer organizations. A cooperative may be defined as an association of persons or institutions who work together to achieve certain commercial objectives. Many cooperatives do not trade (e.g. irrigation, pest destruction and breed societies) but those that do may be put into three categories: market farmer's produce, purchase farmer's inputs and producer collectives, involving joint farming operations from which some surplus is generated. The importance of cooperatives in developing countries is not well documented

[6] Evenson (1982) estimated that US farmers may spend as much as 25% of their time on this type of work.

and the large number involved makes any attempt of complete coverage futile. Like NGOs coops can play an important part in articulating demands from farmers.

Plantations, estates and other large firms. There is no particular reason why plantations should be privately owned. A plantation may be simply defined as a specialized type of large farm. The International Labor Office defines large as more than 5 hectares and at least 10 workers. The specialization issue differentiates plantations from large farms. They cultivate one, or less frequently two, of a restricted range of (mainly export) crops, they have a higher capital to land ratio due to investment in tree crops, processing plants, the large labor force includes a high proportion of permanent employees, unlike ranches and mechanized cereal farms, the labor force is supervised by a small specialized team, following the industrial model (Tiffin and Mortimore 1990). In the context of agricultural research, an important difference between smallholdings and plantations or estates is that whereas farms are normally too small to finance research individually, large plantations may be in a position to undertake research for their own use.

Agricultural research conducted by plantations and by processing industries includes both plant breeding and management. Plant breeding and selection is done, for example, by oilpalm, rubber, pineapple, and tobacco companies and plantations. In addition, plantations invest most of their research resources in developing improved management procedures to reduce input costs. For example, they focus most of their research on ways of reducing fertilizer and pesticide costs. Private plantations probably invest more than chemical companies in integrated pest management research in less-developed countries.

Large cereal farms may have the same characteristics with respect to research as do plantations and will other large scale enterprises, in forestry, ranching and poultry production.[7] Research by large farms and plantations concentrates on managerial technology, such as improving cultural practices in order to minimize costs. Some of these large organizations also develop new inputs. For example some of the most important rubber and oil palm varieties were developed by private plantations. Processing companies and plantations also conduct plant breeding and selection trials for crops like oilpalm, rubber, pineapple, sugar and tobacco.

Commodity institutes. Cash crops are often produced both by small farmers and on plantations, owned by the state or by local or foreign companies. More recently, contract farming is becoming increasingly important, for instance in crops such as beans and tobacco. Institutes performing research for their industries are often financed by charges (cesses) on plantings and production. In the less-developed countries, many commodity institutes are part of the public research systems, but some of the most successful examples are purely or partly private. The definition of private again comes under scrutiny. If the producer levy is voluntary, then the organization is akin to a producer cooperative, but if as is often the case the levy is imposed by government decree and is coercive, it may not differ from an activity financed by any other coercive tax.

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[7] The broiler industry is probably the best example of a large scale oligopoly including research, processing and marketing of the final product.

Technical assistance. A range of private companies operate in the farm sector of developing countries, on a contractual basis, often in collaboration with governments and aid agencies, supplying technical assistance of various sorts, including management skills.

2.3.2 Input industries

Much commercial private-sector research in the less-developed countries is conducted by input industries. This research is mainly of an applied focus and tends to be restricted to the largest companies. Most private companies are not involved in research but on the production, marketing and distribution of inputs.

Seeds. Research by private seed companies consists mostly of breeding hybrids based on the inbred lines developed and maintained by multinationals and public research programs in local institutes, US agricultural universities and CGIAR centers. Both multinationals and local companies have active breeding programs. Most private plant breeding on a world-wide basis is in maize, followed by sorghum and sunflowers. In some countries there is work on hybrid varieties of pearl millet, cotton, rice and wheat. Many companies also breed seeds for horticultural crops, of which hybrid tomatoes are probably most important.

Seed companies focus on variety development, including testing, seed production, and distribution. Their activities may be viewed as a chain - from plant breeding, to variety trials and maintenance, release of breeder seed, multiplication, field inspection, and certification of commercial seed. Some public regulation is required, but individual tasks, such as multiplication, can be put out to private farmers, even if the company is private.

Feeds and animal health products. Livestock feed research focuses on producing new materials to reduce high-quality feed costs (for poultry, meat and dairy). The feed industry is in general not research intensive, most research activities may be largely field trials and product development. The goals of feed research are improving the quality of feed and reducing its cost by using inexpensive sources of protein and energy. Feeds can embody new animal health products and is thus linked to animal health technology. Typically, the feed industry and feed research has been predominantly private.

On the contrary, basic research on animal diseases and breeding is part of the biological technology area and has been a major component of public research. Private research on veterinary pharmaceuticals is mainly conducted by multinational companies which develop a variety of products such as dips and disinfectants and veterinary drugs. The industry is research intensive, spending about 10% of the value of sales on research. Upstream research would tend to be concentrated in more-developed country laboratories, with more applied work being conducted in the regions where the products are sold.

Agro-chemicals and fertilizers. Research in chemicals and fertilizers is largely private and centralized in the more-developed countries. Some of the research at headquarters is done on less-developed country issues, but most of the technology is developed for markets in the US, Europe, or Japan. If the technology is deemed suitable for less-developed countries, it is then tested and perhaps modified. Most major multinational corporations have a few research farms situated in less-developed countries for early screening of new products.

They also conduct research on different formulations, on the ecological impact of new pesticides, and to meet registration requirements.

Initial (more basic) chemical research such as synthesizing new chemicals, screening new pesticides and conducting toxicology tests is usually conducted in multinational headquarters. Screening new pesticides in field trials is conducted at stations in different agroclimatic regions, while the final trials, required for registration are conducted by local subsidiaries. Most major multinationals have a few research farms, situated in developing countries, for early screening of new products. They also conduct research on different formulations and on the ecological impact of new pesticides.

Agricultural chemical companies in less-developed countries undertake little or no research that leads to the synthesis of new chemicals. Taiwan, which does not have a strong patent system, has a sophisticated chemical industry that reverse-engineers products developed elsewhere. In countries such as India and Brazil where the process for producing a pesticide can be patented but the pesticide itself cannot, much agricultural chemical research is oriented toward developing new process technology.

Research in the fertilizer industry can be divided into that aimed at process or at product innovations. The second category may be more limited, but much of the work on new mixes of nutrients to suit particular crops and conditions requires local trials. Most small companies involved in research are producers, who appoint distributors to market their products in a particular region or country. Large companies usually have, in addition to research and production facilities, a marketing division including technical services who set up on-farm trials, field days, and train sales staff and distributors.

Farm machinery and equipment. This is an extremely heterogenous category, ranging from multinational companies in the tractor and combine industry, to local blacksmiths. The large tractor companies spend between 5% and 10% of the value of sales on research, and have substantial "in-house" facilities in the more-developed countries. For other farm machinery and equipment, the research intensity is lower, probably not more than 3% of the value of sales. At the other end of the scale, in the early stages of mechanization, sub-invention and adaptation are almost exclusively done by small manufacturers or workshops in close association with farmers (Binswanger 1984). The locational-specificity of many adaptive solutions gives farmers, blacksmiths and small local firms a comparative advantage over public research institutions and large corporations.

Two types of agricultural machinery research activities are carried out by local companies. The first consists of minor modifications of existing machines. This is usually not done under the auspices of a formal research program. It is, however, quite important in terms of the actual amount of innovative activity (Mikkelsen 1984). The second type is more basic research, involving the adaptation of engines, transmissions, and brakes of agricultural machinery to less-developed country conditions. Several local companies are investing in tractors and irrigation pump research.

On a world-wide basis, the public sector has contributed little on mechanical innovations, where private initiative has been the dominant force. This situation is quite different with the development of biological materials. There are two main causes for this; firstly, a

university education is not a critical requirement to conduct some applied research - mechanically-minded individuals with little formal education are not at a disadvantage. Secondly, the incentives to indulge in the activity are high, since the fact that the innovation is embodied in a saleable piece of equipment allows the inventor to appropriate the potential returns to the investment. Section 3 examines these issues at length.

2.3.3 Processing and food sector companies

Processing of food crops in less-developed countries is dominated by parastatals, but for cash crops there is more private-sector involvement. Food industry multinationals located in the more-developed countries, that deal with products that require inputs produced in the tropics (chocolate, edible oils, sugar) often own and/or manage plantations and processing facilities. Vertical integration may extend in some cases to input suppliers as well.

Research conducted by processing companies such as tobacco companies, sugar mills, breweries and horticultural processors focus on improving productivity of the farms that supply them with the raw materials, and at improving the quality of these materials.

3. POTENTIAL ROLES OF PUBLIC AND PRIVATE RESEARCH ORGANIZATIONS

Although there is no single criterion for determining a public-private boundary the potential roles of both sectors in agricultural research are examined in this section by focusing on each sector's objectives, the areas of research in which they are involved and the types of technology they produce. Special emphasis is given to the arguments for and against public involvement in research given the public-good nature of much agricultural research output.

3.1 A typology of research activities and technology types

A research process consists of several steps that should not be interpreted as independent stages but as part of a continuum from more basic to more applied activities. At the upstream end of the research spectrum, basic research generates new scientific knowledge, with no view as to eventual commercial application. Next in this ordering comes strategic research, which is intended to solve particular problems, or to develop new techniques. Further downstream, applied research aims to create new technology, and by this stage commercial application is envisaged. Finally, adaptive research is required to adjust the technology to specific environments and circumstances, in order that innovation can occur and the technology become a commercial reality.

This stylized sequence of processes has to be extended further in order to link research to productivity growth. A distinction should be made between research to produce knowledge and research to develop technologies. New scientific knowledge adds to the stock of knowledge on which applied research can draw, in order to produce new technology. Then the new biological, chemical or mechanical technology, which may still be thought of as a blueprint, often needs to be embodied in inputs such as seeds, fertilizers, herbicides, insecticides, machinery and equipment before innovation is possible. These improved inputs must be diffused across a considerable proportion of the farm population, before the new technology can significantly affect agricultural productivity and allow the research investment to generate a commercial payoff. In addition, farmers may need to make a considerable investment in screening and adaptation to ensure that the innovation will suit their needs.

Basic research is almost by definition a non-commercial activity. Uncertainty as to the probability of success, the nature of the output and its commercial applications (or lack of them) has tended to make basic research the preserve of public sector and of private firms in high technology industries with great economies of scope and sufficient resources to make the investments necessary to pursue promising outcomes. Even then, the lag between the inception of a research project and its commercial success can be many years. "Near market" research, where commercial realization is in view, is the more apparent domain for the private sector. Since the public-sector has traditionally focused on upstream research while the private-sector has concentrated more on downstream research, the comparison between public and private "research" activities may not be pertinent.

Evenson's (1983) argument for private-public complementarity is based on a classification of the output of research into pre-technology, prototype technology, and usable technology. He argues that private research focuses mainly on the development of usable technology, with some effort on prototype technology and very little in pre-technology. This is because the private incentive system usually stimulates the invention of usable technology but does not

provide protection to pre-technology research. Public research activities are, therefore, important not only in pre-technology development but also in prototype technology development when markets or firms are small, and in usable technology to enhance technological competition.

In sum, at the basic end of the research spectrum public involvement is generally required; however, for the other categories - particularly applied and adaptive research - the situation varies according to the type of technology being considered. We will discuss these types next, while the rest of the section is devoted to the arguments for and against public involvement in agricultural research.

Agricultural technologies aimed at the primary production sector can be broadly classified into four categories that are not necessarily mutually exclusive: (a) managerial: crop and livestock management techniques and other managerial practices; (b) biological: crop cultivars, animal breeds, hormones, vaccines, and other living organisms; (c) chemical: growth regulators, fertilizers, fungicides, insecticides, and herbicides; and (d) mechanical: tractors, harvesters, and other farm equipment.[8]

Managerial (agronomic) technology. Agronomic research such as on crop rotations, planting dates, planting densities, spray regimes and weeding strategies, by their nature require local activity. Since ownership is difficult to establish, the product is difficult to sell and this limits private-sector activity. Although managerial technology is mainly in the domain of the public sector three separate cases can be distinguished where the private sector may be involved: (a) plantations and other large enterprises may conduct research to improve their own productivity and may, or may not be willing to make their findings known to others; (b) input companies, especially in fertilizers and other chemicals may conduct research and disseminate their recommendations to potential clients, in order to sell their product; and (c) processors of agricultural outputs, such as tobacco companies, sugar mills and breweries will conduct research and disseminate their findings, especially to contract growers, in order to secure the quantity and quality of product that they require.

Biological technology. Because patenting of biological material is difficult and copying is possible this type of technology is, with the exception of hybrids, in the domain of the public sector. For example when open-pollinated varieties are developed the farmer need only return to the market periodically. Binswanger (1984) regards public funding to be crucial and Rausser et al. (1981) argue for public involvement at the applied level. Evenson (1982:274) suggests that a natural division of labor has emerged in the US with the public sector producing plant breeding material while the private-sector develops the final product.[9]

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[8] Although there are also other types of technologies (either products or processes) related to agriculture, such as post-harvest and food-processing, this paper focus primarily on these four types.

[9] The controversy over plant breeders' rights demonstrates the actual difficulties involved in arranging appropriate patenting arrangements in seed production. More than 20 countries have passed legislation to enact breeders rights, which should increase the appropriability of returns and hence encourage private-sector research.

In animal breeding (and disease research) much the same arguments apply and the public good aspect is clear. The main foci of livestock research includes breeding and aspects of animal nutrition, primarily pasture and feed research. In addition, there is a substantial amount of research in poultry breeding. Most of this research is conducted at the headquarters of multinational corporations in the more-developed countries, and its results are directly transferred to local affiliates or joint ventures in less-developed countries.

Chemical technology. As with machinery, the private-sector dominates applied and adaptive areas of research to produce agricultural chemicals. However, Ruttan (1982) argues that three types of public intervention are necessary: (a) modified regulatory procedures to ensure that the private-sector develops chemical and biological agents compatible with the goals of output and amenity; (b) expanded support for public sector institutions developing biological and cultural control agents and procedures - i.e. on the biology of insect predators and host populations, the breeding of insect resistant crop varieties and the design of cultural practices to depress insect populations; and (c) public support for the design and operation of insect population management programs. Here the roles of the public and private-sector are particularly ill-defined.

Mechanical technology. On the basis of a wide-ranging research project Binswanger (1984) concluded that "on a world-wide basis, public-sector research has little contributed to machinery development". This is so because the gains from innovation are embodied in machinery, so that companies can appropriate the returns to research investment with the sale of machines. In this sense, most applied and adaptive research to produce mechanical technology should be left to the private-sector. Patenting arrangements are also comparatively straightforward for mechanical innovations, though all forms of patent legislation are weak in most developing countries. At the informal end of the research scale, workshops and small local firms dominate sub-invention and adaptation, and rely on embodiment and a degree of local monopoly to appropriate the returns.

The scope of the public- and private-sectors research activities vary between these technology areas because they have different appropriability levels. This is due to differences in patent enforceability, the ability of rivals to imitate innovations, and the economic life of them (Rausser et al. 1981). Chemical technologies typically have a short economic life span, and benefits are relatively appropriable by the innovator. In more-developed countries, mechanical technologies are usually patentable, and innovators' rights are enforced. In most less-developed countries, where innovators' rights are often not enforced, private firms have fewer incentives to invest in research to develop new products. In the case of mechanical and chemical technologies then, a mixed public and private effort is common in the more basic stages, but it is the private sector that undertakes much of the applied research work.

On the basis of case studies of US public and private research, Ruttan (1982) concluded that mechanical technology will remain a low priority for US public research. More public resources will most likely be devoted to chemical technologies in the areas of new pest control methods that use fewer chemicals. In biological technology, public resources will probably be reallocated from plant breeding per se to more basic supporting areas such as genetics, physiology, and pathology.

Albeit private research activities have concentrated on developing mechanical and chemical technology, and less on biological and managerial technology with advances in biotechnology, private research on biological technology is increasing (Persley 1990) and there is some expectation that biotechnology will alter the balance between large and small companies in the future since it increases the advantage of large companies due to the cost of the investment required. This and the patentability of biotechnology products can also be expected to shift the public-private boundary. Plant protection has been a factor influencing the type of technology being developed. Although the legal framework in many countries offers certain rights to research organizations for appropriating some of the potential benefits of new technology, effective protection of those rights is quite difficult to achieve.[10]

Given the difficulty of capturing benefits from managerial and biological innovations, unless covered by patents or a plant variety protection act, public research has a key role to play in supporting both the generation and diffusion of those technologies.

3.2 Arguments for and against public intervention in agricultural research

Much new knowledge produced from research has the nonrivalness and nonexcludability characteristics of a public good. Nonrivalness means that the research output is available to everybody at zero marginal cost. A purely "rival" (private) good or factor is one such that the use of a unit by any agent precludes its use entirely by anyone else. Knowledge in this sense is a pure public good, i.e., one for which the use by any agent has no effect on the amount available for use by others. Consider, for instance, the development of a new crop-rotation pattern that improves crop production and reduces soil erosion. The use of this information by a particular farmer does not prevent the adoption of the same practice by other farmers.

The second attribute, nonexcludability, implies the infeasibility (or high cost) of denying use to those who do not pay for it so that a "free rider" problem is present. For a nonrival (public) good, exclusion does not have the same importance as for private goods. Since the marginal social cost of a new user is zero, it is not socially optimal to set prices that will exclude anyone who benefits from the public good, i.e., exclusion is economically inefficient. A common aspect of the products of agricultural research is that many are nonexcludable.

Private firms usually do not produce goods that are nonrival or nonexcludable (like most public goods) because they would be unable to capture benefits to cover the costs resulting from their research activities. Farmers seldom conduct formal research because farms are small and capture only a small part of the benefit of an innovation. A socially optimal level of public good will, therefore, not be supplied if its production is left to private firms. Since information is not perfectly appropriable by its discoverer, the excess of the social over the private value of new technological knowledge leads to underinvestment in inventive activity. Consider, for example, the development of an open-pollinated variety of a crop in a country with no plant variety protection. After it is released, it can spread among farmers without

[10] Once the technology is made available, the costs of replication may be negligible compared with the costs of initial discovery. An exception is hybrid seed, which cannot be reproduced from its own seed.

benefiting the inventor. Hence, private firms alone would typically produce nothing or at least suboptimal quantities of such a technology.

Moreover, the private-sector would probably fail to meet important objectives that cannot be attained under a system driven only by the profit motive. Although the public sector has failed to meet many development objectives in many countries it is intrinsically capable of meeting needs that a private company cannot. Private research may be quite different from public (in terms of factor-saving biases and client groups) and may be at odds with what is required of the public research system in meeting development goals, such as poverty alleviation. The private non-commercial sector may be in a position to assist the public sector in attaining these objectives.

Thus, we need to ask, what can the private-sector (commercial and non-commercial) do better than, or as well as, the public in helping the whole system meet its objectives? What can the private-sector be encouraged to do, in order that scarce public resources can be used to pursue goals that are outside the scope of the private-sector? This is not a static problem; appropriate institutional changes create an environment in which the private sector can contribute, but such changes are evolutionary, and the time dimension is easily neglected. Continual policy changes, based on rapid judgements that policies are not succeeding, simply adds to the level of uncertainty and increases the private-sector distrust of the government. In any investment activity there are lags between disbursements and realizations, yet in research they are particularly long. The private-sector must take many risks but the danger that the government will continually change the rules should not be the greatest cause of uncertainty. A reasonable degree of stability is a precondition for private activity.

Private underinvestment in research is a strong argument in favor of government intervention in the supply of new technology. The most common types of intervention are government funding of research and legislation on intellectual property rights such as patents, which endeavor to ameliorate the nonexcludability attribute. The rest of this section reviews some of the theoretical arguments for and against public-sector intervention in research, drawing on Thirtle (1986).

3.2.1 The basic case for intervention

It is widely accepted that to maximize social welfare, public intervention is necessary in cases where markets fail. An economy with perfectly competitive input and output markets and with no unpriced externalities is supposed to achieve this ideal state. Thus, monopoly and spillovers lead to inefficient outcomes and both occur in the allocation of resources to research. Arrow (1962) argued that the private-sector will underinvest in research for three reasons: inappropriability, uncertainty, and indivisibilities.

Inappropriability. Lack of appropriability of returns to investment in research by private firms is the fundamental cause of market failure. When the information generated by the research process has public-good attributes and if social benefits are greater than private profits, then the profit maximizing allocation of resources to research by a private firm will not be socially optimal.

Demsetz (1969) rejects Arrow's argument on the inappropriability of returns to new knowledge, arguing that appropriability is largely a matter of effective institutional arrangements (particularly patents) combined with adequate enforcement. The public-good character of new knowledge is also dismissed, as arising from an illegitimate "partitioning of economic activity into the act of producing knowledge and the art of disseminating already produced knowledge".

Uncertainty. Uncertain outcome is an essential characteristic of the research process that cannot be insured against. Therefore risk averse firms will discriminate against investments with uncertain outcomes, again leading to an allocation of resources to research that is less than socially optimal.

Implicit in the arguments for intervention in cases of risky investment is the proposition that risk is "socially irrelevant". This has been contested by Hirshleifer and Shapiro (1977) on the grounds that if the theoretical arguments are carried over to using lower discount rates for government projects, the result is an undesirable "optimistic bias". Government projects are as prone to failure as private ones.

Indivisibilities. In the context of a firm that supplies agricultural inputs and conducts its own research, indivisibilities or increasing returns in use means that the fixed cost of producing a given innovation can be spread over more units of output by a large firm than by a small one. If increasing returns to scale prevail for any reason, then elements of monopoly power must be expected and all else being equal, monopolists produce less than is socially desirable. The basic case against nationalization or regulation of monopoly is that stated originally by Friedman (1961). Monopoly is transitory and relatively unimportant but becomes institutionalized, permanent and more of a problem with public-sector involvement. Hence it is best left alone.

In all three cases, private investments become increasingly inadequate the closer the research is to the basic end of the spectrum, since basic research is defined as the disinterested pursuit of scientific knowledge without a specific technological objective in view. Therefore it follows that the more basic the research, the more public-sector support becomes necessary.[11]

3.2.2 Other reasons for public intervention

Rationales other than the public-good argument, have been advanced to justify public involvement in agricultural research. There are a range of further reasons for public intervention based on the theoretical standpoint of the welfare economics literature on the "public interest". Some of these arguments are briefly discussed below.

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[11] Inappropriability, uncertainty and monopoly are inter-dependent. Appropriability is greater for larger firms and monopolies, which also suffer less from uncertainty, being able to pool many research projects to reduce risk. Thus inappropriability and uncertainty both tend to generate monopoly and are reduced (but not eliminated) in the process. This relationship lies behind Schumpeter's hypotheses on the innovational advantages of large firms and monopolies (listed in Kamien and Schwartz 1982).

Underinvestment in research. Empirical support for public intervention in agricultural research is based on the evidence of market failure in the allocation of resources to research. This evidence rests on calculations of returns to research investments. For instance, Echeverría (1990) lists more than 130 studies that calculate rates of return to research investments. The great majority of these studies estimate, regardless of the choice of methodology, social rates of return usually in excess of 20% and often much higher. Thus, despite the inaccuracies inherent in rate of return estimates, the results are interpreted by most economists as evidence of persistent underinvestment in agricultural research.[12] This interpretation rests crucially on the proposition that for economic efficiency the (risk adjusted) rates of return should be equalized for all investment opportunities. If research investment gives a higher return, it follows that insufficient funds have been attracted to drive returns down to normal levels and public intervention is justified.[13]

Preserving competition. Ruttan (1982) suggests that an "argument that has been made for public-sector research is that it has contributed to the maintenance or enhancement of a competitive structure in the agricultural production, input and marketing sectors. There is, for example, considerable evidence that the flow of new technology from public-sector research has contributed to competitive behavior in the seed and fertilizer industries".

Equity. Another argument for public intervention is that the direction of private research could be biased. It would concentrate on producing knowledge that could be embodied in private goods such as agricultural machines and pesticides, rather than new crop rotations or biological pest control, which may be more valuable to society. Even joint ventures between private and public research can be biased against the interests of society (Ulrich, Furtan, and Schmitz 1986).

Economics has attempted to concentrate on efficient allocation arguments leaving the value judgements associated with intervention on distributional grounds to be solved independently by lump-sum transfers. In agricultural research, rational private companies can best make profits by targeting larger, successful commercial producers as their market. Research to produce technology relevant for resource-poor farmers may thus have to be provided by public institutions. If such efforts are not made, the distribution of income must be expected to become more unequal and farmers without access to new technology to fall further behind.

Discounting the future. The preceding efficiency arguments are essentially static, i.e. allocation in one period. A new range of problems arises with the question of the efficient allocation of goods and services between present and future generations. The effect of risk

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[12] The reasons for this situation are discussed in Oehmke (1986).

[13] Peterson (1976) has shown that if research is carried out by private firms and if the new technology is adopted, social returns to private research must be greater than private returns. Griliches (1958) has also argued that the difference between social and private rates of return is a necessary but not a sufficient reason for public intervention, because private returns may still be high enough to induce firms to invest in research.

aversion on investment could lead to socially inefficient inter-temporal choice. In particular, Pigou (1929) argued that the state has a duty to protect the interests of future generations.

Appropriate portfolio of projects. Nelson (1982) concludes that market failure in the case of research is not a matter of too few resources, but the inability of the market to spawn the appropriate portfolio of projects. This is so because of two reasons. Firstly, patent protection or industrial secrecy leads to duplication or near duplication of efforts. Discovering that which is already known or devoting resources to product differentiation for its own sake has little social value. Secondly "major theoretical uncertainties call for a variety of approaches with open knowledge of routes being explored and what is being found along the way, and not for a big push along one particular road" (p.480).

Nelson also conjectures that in industries where there was public-sector (particularly university) involvement in basic research, information exchange was wider and deeper and technologically advanced faster. Particularly the treatment of research results as public property is contagious, being quickly caught by the private-sector researchers in the industry. Reflecting on the agricultural sector Nelson concludes that in the US the government defined certain areas, where information flows were particularly important to be non-proprietary and proceeded to fund research in these areas. In applied research a reasonably well-defined division of labor between publicly and privately funded research has emerged.

Unemployed resources. Previous arguments for intervention rest on the standard theory of welfare economics, which assumes that the economy has no idle resources. Efficiency arguments that are the province of the allocation branch of the government are conducted on the assumption that the distribution and stabilization functions will be performed independently. Yet technology affects employment, and in any country with rapid population growth, employment generation may be as much of an objective as productivity growth. Particularly, it is possible that a privately profitable innovation could have negative social benefits, if for instance, displaced labor can find no alternative employment. If research is conducted by the public, or private-sector, for the benefit of large farmers, the consequences for small farmers or landless laborers may be adverse.

Complementarity with education. Another argument that suggests that the market allocation of resources to research may be inadequate is the strong complementarity between public-sector investment in agricultural research and education (Ruttan 1982).

Institutional innovation. Institutional innovation is interpreted by Hayami and Ruttan (1985) as an economic response to changes in resource endowments and technical change. They define institutions as the "rules of a society or of organizations that facilitate coordination among people by helping them form expectations which each person can reasonably hold in dealing with others". They include the rules by which the economic game is played, more or less efficiently, and have usually been regarded as a legitimate, or even essential, area for state intervention.

Environmental concerns. The effect of new technology on public goods such as the environment, health, safety and water resources has recently attracted increasing attention in the issue of sustainable development. So long as private firms view environmental

resources as free goods, there is no incentive to develop technology that economizes in the use of these resources. It could be argued that broadly based public-sector institutions may have an advantage over private input producers in these circumstances.

Imperfect knowledge. Another justification for government intervention is the ideological prejudice of governments that believe that markets don't work. For example, despite the legacy of Adam Smith, British colonial administrations set up marketing boards in Africa partly because they thought that the stability and order of a controlled market had to be superior to the disorderly appearance of a competitive market.[14]

Policy interventions. The reasons for public intervention listed above may seem to explain little about the causes for government activity. In this context policies become one of the key aspects to consider. For example, the control of food crop marketing and processing by parastatals appears to be an invalid intervention, until policies are taken into account. However, if a government decides to implement pan-temporal or pan-territorial pricing, perhaps to secure food security goals, these policy interventions can be explained on public good and distributional grounds. These policies require public control of food grain supplies and usually lead to the suppression of private activity, because private traders can undermine the policies.

The arguments listed above justify the role of goverments, they stress the need for public intervention where there is a lack of markets, or where markets fail. In the shorter run this may call for public provision or the creation of a quasi-market. In the longer run, the public sector should aim to assist in the evolution of markets and other appropriate institutions, such as trade secrets laws and patents, which create markets.

Establishing the case for market failure in research resource allocation in less-developed countries is hardly necessary. In these economies market failure is probably the norm rather than an interesting special case. Where input and output markets are incomplete or non-existent, the role of the public sector must be expected to be greater than in economies where markets are well developed. Since the development process involves the establishment of institutions such as markets, a general principle follows - the lower the level of development, the greater is the pervasiveness of market failure, and thus the greater the need for public provision of agricultural research. As institutions that provide an environment in which the entrepreneur can appropriate the returns to investments in technology are developed, then the private sector can be expected to play a major role in research.

3.2.3 Government failure

In economic terms, private markets are efficient if they produce the goods and services that consumers prefer, at their level of income; production is efficient if there is no slack in the economy by which more or better goods could be produced to make everyone better off. When these desirable properties do not hold, markets do not function effectively, i.e. they

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[14] There are good reasons for the existence of marketing boards, such as the control and promotion of exports by a single body that may be able to exert some monopoly power in trade, to the advantage of the country. But the literature suggests that this reason was subsidiary to a distrust of the market process.

"fail". So Governments intervene with several "remedies", such as regulation, taxation, subsidies and production at public expense. However, it should not be taken for granted that Governments will be willing or able to improve market failure, because the information available to them may be worse than that available to the private sector. Furthermore the public sector may respond more to political pressures than to consumers preferences. So the possibility of Government failure as well as market failure should be considered. That is, even if markets are faulty, public-sector remedies may be worse.

There is clearly a well defined body of opinion that is opposed to government intervention in the economy as a matter of general principle. Rather than attempting to explain this phenomenon in detail, from the beginnings of laissez-faire to the emergence of the new right, this paper simply identifies some important arguments against public intervention. For instance, there are some ideological objections to public intervention in any form for those who believe, like Simon (1948), that individual liberty is dependent on the preservation of market capitalism, which is threatened by state intervention. Similarly, those with a normative belief in laissez-faire hold "that it is wrong to entrust the control of resources to government officials no matter what social objectives they may be pursuing" (Reder 1982).

There are also positive objections to public intervention. For example, Reder (1982) defines the Chicago position with respect to positive economics as leading to anti-statism by way of a belief in the efficiency of market capitalism, especially as a progressive force, combined with a view that the use of agents always dissipates the gains from the division of labor because they pursue their own self-interest. Rent-seeking is the norm and the state is an agent that is exceptionally difficult to monitor and control and is thus an inefficient means of pursuing any objective.

In reply to Arrow's paper, Demsetz (1969) argued that market failure is a necessary but not a sufficient condition for government intervention. Arrow's "nirvana" approach compares existing imperfect institutional arrangements with an ideal norm. The appropriate "comparative institutions" approach compares the existing arrangements with an alternative real set of arrangements, raising the possibility that government failure may lead to a less efficient outcome than market failure. There is a considerable literature on this topic, associated with Friedman and his allies. Their basic position rests on a dismal view of human nature; although the market outcome may be severely imperfect, the impersonal forces involved are unlikely to lead to such poor results as are obtained when the system is handed over to the control of individuals; then we must expect a lack of incentives, corruption, discrimination and rent seeking. Furthermore they attack the notion that the government can do better than the private-sector in areas where information deficiencies are the cause of market failure, by questioning the implicit assumption that the government has access to superior information.

4. PRIVATE AGRICULTURAL RESEARCH IN LESS-DEVELOPED COUNTRIES

Private-sector agricultural research is growing in a number of countries, in spite of the fact that much of the output of research has the characteristics of a public good. This section examines the reasons why firms invest in agricultural research, the complementarities between public- and private-sector research, and the scope of private research activities.

4.1 Determinants for private investments in research

According to neoclassical economic theory, firms seek to maximize expected profits. This objective can be translated into three main determinants that influence the nature and the level of private investments in research: market factors, a firms' ability to appropriate economic gains from research, and the technological opportunities for innovation (table 2).

Table 2. Determinants for private-sector investments in agricultural research

Determinant		Factors influencing determinants	
		Economic and technical	Government policies
Market factors	Expected demand	Income growth Income elasticities Export demand Demand elasticity	Agricultural price policies Import/export policies
	Input Prices	Level of industrialization Supply and demand of inputs	Input price controls Credit policies Government supplies Input import policies Industrial policies
Appropriability		Nature of technology Market structure	Public research effort Anti-rust policy Patents and plant breeders' rights legislation Enforcement of rights
Technological opportunity		Private local research Foreign technological developments Quality and cost of scientific inputs	Public research International research Policies on multinationals Technology import policies Output of universities Subsidies on research costs Imports of research equipment

Source: Pray and Echeverría (1991)

The factors influencing the three determinants are classified, in table 2, into two groups: economic and technical, and government policies. The structure and efficiency of the linkages between the public and the private sector is affected by the amount and type of research being conducted by both sectors as well as by how much government policies and

regulations discriminate or encourage private-sector participation. For instance, research and trade regulations affect private research directly, as well as general agricultural and economic policies that have an indirect effect on private companies decisions to invest in research. Public funding of research in public- or private-sector organizations is one of the main policy instruments that governments possess to influence the degree and the direction of technological change.

The policies and regulations which have most impact on the private sector are those concerned with: research permissions and approval of new technologies (certification and registration procedures); specific conditions on multinational companies (repatriation of profits and foreign ownership); property rights (patents, plant variety protection); trade and price regulations; and tax incentives for research.[15]

Restrictions on multinational companies are very common. Many countries allow companies to operate only if they establish joint ventures with local companies; some countries require majority local ownership of such ventures and in some cases certain industries are completely reserved for local ownership. The amount of profits that can be repatriated may also be restricted. On the other hand examples of tax incentives for research such as cancelling taxes on research expenses, and the reduction of import duties on specific research inputs, are not very common.

Market Factors. The key market factors are expected demand and input prices. Food and agricultural processing industries will not conduct research unless they expect a profitable level of demand for processed goods. The role of demand in inducing seed firms to innovate was demonstrated by Griliches (1957) in his study of the diffusion of US hybrid maize. Schmookler (1966) also emphasized the role of demand in his work on industrial patenting. Anecdotal evidence suggests that expected demand is an important factor in companies' decisions to invest in research in less- as well as more-developed countries.

Most economics literature emphasizes the importance of relative input prices in determining the direction of research and thus of technical change. For example research conducted by plantations is aimed at reducing production costs. Input prices also influence the level of private research. In addition to input prices, the price-policy environment affecting private companies includes product pricing, taxation, exchange rates and credit.

Appropriability. Investment in research also depends on the firm's ability to appropriate the gains from innovation. This ability depends on four main factors. The first is the structure of the industry. Schumpeter (1950) argued that large monopolistic firms would have higher rates of technical change than small competitive firms. Scherer summarizes the findings of subsequent research on Schumpeter's theory: "A bit of monopoly power in the form of

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[15] In addition to the government practices and policies listed here a number of other factors can constrain private companies decisions, such as basic infrastructure, financial systems, the availability of management skills, and social and cultural traditions.

structural concentration is conducive to invention and innovation, particularly when the advances in the relevant knowledge base occur slowly. But very high concentration has a favorable effect only in rare cases, and more often it is apt to retard progress by restricting the number of independent sources of initiative and by dampening firms' incentive to gain market position through accelerated research and development" (Scherer 1980, p. 438).

The second factor is the nature of the technology. Some innovations, by their technical nature, are more appropriable than others, a hybrid variety gives its inventor a monopoly if the inbred lines required to produce the hybrid can be kept secret. Private-sector plant breeding is almost entirely devoted to hybrids of cross-pollinated crops; they give their developers the ability to preclude others from easy duplication and help to ensure a market because farmers buy seed every year to get maximum yields. The third factor is lead time. If a firm can keep improving its product or developing new products more rapidly than its competitors, it can charge higher prices and can thus profit from the research on the product.

The fourth factor is the existence and enforcement of patents and plant breeders' rights legislation. A large body of literature has developed around the value of patents as an incentive to research and on the costs of patents to society (Scherer 1980; Griliches 1984). Surveys of firms in more-developed countries find that firms feel patents are an important stimulus to research. Patents allow firms to exclude others from using an invention. Some studies of the impact of the US Plant Variety Protection Act found that it had a positive impact on private plant-breeding research (Perrin, Hunnings, and Ihnen 1983; Butler and Marion 1985).

In the absence of breeders' rights laws, seed firms will focus their research on hybrid crops because self-pollinated crops can be reproduced and sold. The nature of agribusiness companies dictate that whenever possible they will try to own or license their varieties, and also the processes, genes or plant parts that make their lines unique. In the US utility patent laws also applied to plant breeding (see Duvick 1989). In most less-developed countries however, breeders rights protection and other forms of patent regulations are not available, and when available, enforcement is usually weak. Patents strengthen property rights to new technology. They require the disclosure of a new technology to the public and also provide the basis for market links between companies that develop new technologies and those who only market them. In the absence of patents, companies protect their new technology through trade secrets which restrict the flow of technological information and may reduce the incentives to license the technology widely.

Technological Opportunity. Expenditures on research are also influenced by the potential for development of new technology. The relevant dimension of this potential from the perspective of a private firm is the cost of producing an innovation relative to expected profits. Technological opportunity can be divided into a physical component related to the technical efficiency of the research process, which depends on the state of knowledge and research management; and a price component that depends on the supply and demand of research inputs.

Research by other firms can also lead to new technological opportunities. One purpose of patents is to ensure that the technology embodied in an innovation can be made public for other firms to use in making further innovations. Another way to learn about other firms'

research is through reverse engineering. A third way by which knowledge is frequently transferred is by hiring another firm's scientists and engineers. Yet another source of technological opportunity is local adaptation of foreign ideas and innovations. For example, farming implements such as power tillers quickly become models for local tillers, which are modified to meet local conditions.

Judiciously targeted public-sector agricultural research can also increase technological opportunities for private research. For example, the private hybrid maize breeding programs in Southeast Asia are based on genetic material that confers resistance to downy mildew, identified by the Kasetsart University-Rockefeller Foundation maize program in Thailand.

4.2 Complementarities between public- and private-sector research

With an expanding role for private agricultural research, arguments for less funding for public research may be common in the future, the more so given widespread pressures to reduce government budget deficits. Such an argument presumes that public and private research are substitutes for each other. In many instances, however, they are complementary activities. Basic public research provides opportunities for firms to profit from research and to accelerate the spread of publicly produced technology by adapting it to the needs of farmers. Whether a specific public research program substitutes for or complements private research is an empirical question.

In general, the public and private sectors are not simply direct substitutes because they are involved in conducting and/or funding different types of research to produce different types of technology. An exception is in some biological research where there is more potential competition. As discussed in Section 3, private agricultural research tends to be more applied than public research, and it concentrates more on mechanical and chemical technology. The public sector does most basic research, and it is more involved in biological and agronomic technology. It is also a major contributor to human capital, the supply of which is a necessary condition for the conduct of research in both sectors.

The previous section suggests that the role that can be played by the private-sector will be greater, the easier it is to appropriate the returns from investments in research.[16] Appropriability is a function of the type of research and also of the area of technology. Private-sector incentives to conduct or fund research will be weak in: (a) basic biology and physical research; (b) generic research with broad application across commodities; (c) for areas of technology where knowledge cannot easily be embodied in property produced, such as most agronomic research; and (d) where the institutions to protect intellectual property rights are ineffective. In general private incentives are greatest in mechanical technology, followed by chemical, then biological, with managerial technology the least attractive investment.

[16] The level of risk will also be relevant, this will partly depend on the lag between investment and realization of returns.

This continuum suggests that there is complementarity or synergy between public and private research - in the cases just listed, research must be conducted or supported by the public sector or it will probably not get done at all. This is a powerful argument for public intervention in the allocation of resources to research. The public sector must cover the basic end of the research continuum and if it should fail to do so, there will be no downstream private research and hence no productivity growth. In addition, exists public-private complementarity by type of technology, with the public sector focusing on the least appropriable types of technologies.

The argument above is essentially static. Introducing dynamics adds a further form of complementarity, for applied research produced results by exploiting the fact that technological practice lags behind the scientific frontier. It follows that if basic research fails to push the frontier forward the pool of scientific knowledge to be exploited will diminish and applied research will have diminishing returns.

These two forms of complementarity are more dominant the longer the relationship between the public and private-sectors in agricultural research, but there is also a degree of substitutability. In biological research, for example, the public sector controls upstream activities, like basic genetic material, and the private-sector can perform well in near market areas, such as the seed industry. The boundary between the two is variable and either sector, or both, may indulge in plant breeding. Indeed, a degree of overlap will often exist, which may be a waste of resources, or may be an area of competition that increases efficiency. For example, private competition could provide an incentive to greater efficiency from public seed companies.

It has been argued in this paper that the boundary between the public and private sectors depends on the type of research being considered and on the particular area of technology it applies to. In addition other factors will also affect that boundary such as the degree to which markets have developed. Where the public sector is the producer and in most cases also the supplier of inputs it is reasonable to assume that there will not be (commercial) private research activities. To the extent that the emergence of markets is a function of the development process, this must severely limit private activity (the market and private are practically synonymous) where the level of development is low. This may account for the lack of private activity, for example in sub-Saharan Africa.

Other factors also play a part in defining the size of the private-sector. All else being equal, the private-sector should be relatively larger in economics where: (a) there is open trade that fosters commercialization, and commercial development has not been stifled by regulation; (b) the cultural endowments were amicable to the creation of institutions that encouraged commerce; and (c) there has not been opposition to the market on ideological grounds.

Table 3 shows possible interactions between the public- and private sectors in funding and executing research. Some of the mechanisms described in the table confirm that national research, public and private, and international research reinforce each other. The table follows the earlier classification of public and private organizations arranged by commercial and non-commercial performance. It shows a total of four possible combinations of public and private funding and/or execution of research.

Table 3. Potential public- and private-sector research interactions

FUNDING / EXECUTION		PUBLIC SECTOR	PRIVATE SECTOR	
			Non-Commercial	Commercial
PUBLIC SECTOR		Research Institute Parastatal Regional research network	Foundation	Joint-ventures Contracts
PRIVATE SECTOR	Non-commercial	Non-Government Organizations	NGO Foundation	NGO
	Commercial	Joint-ventures	Cooperative	Input companies

There are also five other possible combinations defined by each sector executing its own funded research. For instance, a public research institute and a private input company are examples of both sectors funding their own research activities. Yet there are other possible public-private combinations depending on which sector funds and/or executes the research activities. See for example the position of parastatals, NGOs and joint ventures in Table 3.

The table also depicts alternative sources of funding for public institutions that might be more sustainable than current arrangements may be established by having direct beneficiaries of public research, such as companies and producers, contribute to cover research costs.

The interaction between private- and public-sector research could take place through formal and informal channels. Formal links consist, among others, of contract research, consultantships, cooperative research projects, and joint ventures. Private companies may buy technical information for their research activities by hiring scientists from universities, government research programs and consulting firms. In addition private companies fund specific projects (or researchers) in universities or research institutes. The interests of both parties are usually clearly defined. In the US for example, universities have freedom to research and publish the results while private companies commercialize the results. Also, universities have first rights to patents and companies to license on those patents. Industry can make occasional research grants to public laboratories aimed at basic research or to other public institutes for training. Trade secrets could also be shared in public-private joint ventures. So there are, in general, many possibilities of collaboration at the research and commercialization levels and also at the policy level to develop intellectual property protection.

A common example of formal public-private interaction are the annual variety trials conducted by national research institutes. These trials include varieties developed by both sectors. Public institutes publicize the results including yield and disease resistance performance. There is a fixed charge per-site to private companies. Also seed companies might obtain or pay royalties for basic seed of public origin.

An example of a joint public-private research project in which scientists from both sectors worked together on the same project is rice research in Colombia. An international and a national research center (CIAT and ICA) do breeding and introduction of varieties while the rice growers association (FEDEARROZ) evaluates the varieties in farmers fields and performs some crop management research on the improved varieties.

The public-private joint research ventures in Argentina are an example of contract research. The national research institute has developed two types of links with farmers' cooperatives and private companies: (a) technology transfer through specific agreements where the institute licenses publicly produced technology such as finished plant varieties, and charges a royalty; and (b) agreements to conduct joint research (Moscardi 1991). In these joint ventures the public sector finances infrastructure and basic salaries of researchers while private companies fund operational costs and a premium on salaries. The innovations produced as a result of these ventures are then patented. In this sense ventures formalize complementarities between the sectors for the case of proprietary technology.

Examples of informal channels of communication between public- and private-sector researchers are scholarly journals and professional meetings. Informal public-private links are usually accomplished at the individual scientist level. There are three main reasons for this: researchers from both sectors have often studied at the same university, the number of researchers working on a specific topic is small (i.e. they know each other), and many private sector researchers initially worked in the public sector.

The public and private sectors are also linked, formally and informally, in transferring technology when private companies market publicly developed technologies or when public extension systems transfer privately developed inputs.[17]

The private sector can collaborate with the public sector in several areas, such as: joint research, provide human, technical and financial resources necessary to insure implementation of a mutually beneficial research agenda, take the lead in carrying out and financing downstream activities, such as input supply, post-harvest and processing research, marketing and transferring of technology. To accomplish some of these activities, it will certainly take a well developed private-sector.

An example of how the participation of the private sector and the interaction between both sectors could be encouraged is by establishing a national science and technology council, or a foundation that could act as an intermediary between the sectors. This council could develop a national plan where public- and private-sector priorities are defined, creating a broad constituency base of support for agricultural research. Two other examples of possible interactions are: contracts and joint ventures between public and private sector organizations; and consulting/advising of public staff on private companies and vice versa, participation in professional societies, sabbaticals and exchange programs.

A more rational division of labor, particularly when public institutes set research priorities, could also be accomplished if institutes have better information on private companies

[17] See Pray and Echeverría (1989) for a more thorough discussion of these links.

activities. In addition more public sector attention to research policy issues that improve knowledge about costs and benefits of different policy alternatives is needed. For example a discriminatory agricultural input import "protection" policy could benefit the local industry including subsidiaries of multinationals but not the farmer who pays a higher price. Also at the policy level, the development of a national agricultural development and research plan in collaboration with the private sector with clear division of responsibilities could certainly improve the interaction. The involvement of the private sector in setting a national research agenda could take place, among others, by direct communication with public research institutes, by lobbying at ministries related to agricultural research programs, and by participating in executive boards of public research institutes.

An improved public-private interaction will encourage cooperation to serve the public interest paying special attention to the fact that farmers' needs and market demand should have a significant input in the process of technology generation and transferring, rather than the other way round.

4.3 Scope of private-sector research activities, a regional perspective

As mentioned before agricultural research conducted and/or funded by the private sector is largely concentrated in the more-developed countries. Among less-developed regions, Latin America appears to have more private research than Asia, whereas Africa is lagging far behind.[18]

Private research, especially in less-developed countries tends to be applied in nature. For instance the seed industry concentrates mainly on breeding hybrid cultivars of maize, sorghum, and sunflower. International seed companies develop new hybrids by crossing their elite lines with local germplasm while local companies use the results of public research to develop hybrids. Agricultural chemical, veterinary pharmaceutical, and poultry breeding research are almost entirely conducted by multinational corporations. Multinational chemical companies screen new products at various agroclimatic zones while local subsidiaries conduct final field trials and the tests required for registration. Most private research in agricultural machinery takes the form of experimentation by implement producers, who incorporate modifications suggested by their staff and by farmers.

Table 1 provided a brief outline of private-sector organizations involved in agricultural research. On the basis of the scattered information available we will now look in more detail at some of these categories on a regional basis. A list of multinational and local companies involved in agricultural research in Latin America and the Caribbean, Asia, and sub-Saharan Africa is presented in Tables 4, 5, and 6 at the end of this section. What follows is in a very preliminary manner a discussion of the extent of activities conducted by the organizations listed in such tables, systematized by region, and when possible by type of organization, technology and area of research.

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[18] Pray and Echeverría (1991) estimated an yearly average of multinational research expenditures during 1985-90 in Latin America and the Caribbean, Asia and Pacific, and sub-Saharan Africa, to be approximately US$17 million, US$14 million, and US$5 million, respectively.

Although the list of organizations included in Tables 4, 5 and 6 is far from exhaustive, there are a sufficient number of examples to show the diversity of private sector activity. The categories of private-sector organizations defined earlier overlap, since agricultural research may be carried out by companies (national or multinational), by groups of individuals (cooperatives, NGOs), or by foundations or commodity institutes that fit neither category well. If a company or group is involved in the production process, it may be an input supplier, an agricultural producer, or a processor of agricultural output. But it could also be a vertically integrated company that undertakes more than one activity, or it may be a group, like an NGO, with no stake in the production process, and an ability to provide services wherever they are needed.

4.3.1 Latin America and the Caribbean

More private research seems to be conducted in Brazil than elsewhere in the region. In Argentina and Chile, most private research is conducted by seed companies (table 4). Plant breeding research is concentrated in countries with large areas planted to maize, such as Argentina, Brazil, and Mexico. There is some research on agricultural machinery by multinational corporations in Brazil but little elsewhere in the region. Plantation research is carried out in a significant way in Central America and Colombia. Research institutes funded by producers' associations are very common in Colombia.

In Latin America the ratio of research carried out by multinationals compared to domestic agricultural research seems likely to be higher than in the other regions. In Argentina, private hybrid maize, sorghum, and sunflower breeding is almost entirely done by multinational corporations, and they have a strong position in those crops in Brazil. However, several Argentine companies have wheat research programs, and the largest Brazilian seed firm is locally owned (Jacobs and Gutierrez 1986). In Chile all hybrid maize seed comes from the US with very little local research input, but wheat and rice breeding is carried out by local private companies and farmers' groups (Venezian 1987). Echeverría (1990a) found that 25 companies in Mexico spent a total of US$ 1.7 million on maize research in 1987. Of this, US$ 1.3 million was spent by four large multinationals and the rest by local companies. In Argentina none of the tractor companies, multinational or local, has a formal research program (Huici 1984). Dahab (1985), in a study of the Brazilian agricultural machinery industry, found that only 11 of 49 firms conducting research were owned primarily by foreigners.

In addition there is private research, conducted mainly by farm sector associations, in animal breeding (beef, dairy, and sheep) and some research on improved pastures and management of large livestock/crop operations. There is a limited amount of research on veterinary pharmaceuticals, mainly through local affiliates of multinational companies. Consulting firms in the southern part of Latin America also conduct applied research on agronomic practices such as fertilizer application and pastoral management for ranches that specialize in livestock and crops, and transfer information from public research stations. Also, farmers' organizations hire experts to provide technical advice on farm management and conduct applied research on managerial technology.

4.3.2 Asia

According to Pray and Echeverría (1991) the estimates of total private research expenditures in Asia ranged from $17 million in India to negligible amounts in Bangladesh. Multinational corporations in Asia concentrate their research on seed, agricultural chemicals, and plantations. There is seed-industry research in India, Thailand, and the Philippines. Asian agricultural chemical research is concentrated in the Philippines and Thailand (table 5). The only poultry breeding programs done by multinational corporations outside the US and Europe are two joint ventures between Indian and French companies.

Research by multinational companies on animal feed or veterinary pharmaceuticals is very limited in Asia. Most private plantation research is in Malaysia, with some important research programs in Papua New Guinea and Indonesia.

In South and Southeast Asia, multinational corporations conduct between 35% and 40% of the total private agricultural research effort and the rest is undertaken by locally owned companies. Multinational corporations spend more than local firms on plant breeding and pesticide investigations, about an equal amount on plantation research, and almost nothing on agricultural machinery and livestock research. The Indian hybrid seed industry is largely locally owned. Seventeen companies had research programs in 1987, but only two of those programs were controlled by multinational corporations (Pray et al. 1989).

4.3.3 Africa

Private-sector research is conducted mostly in the commercial agricultural regions of Kenya, Malawi, Zimbabwe and some on the West African countries (table 6).[19] Similar to Latin America and Asia, two types of private organizations conducting and/or funding research seem to predominate in Africa, multinational input companies and commodity organizations. This varies considerably among countries. Multinational input supply companies have strong research programs in a few countries. Commodity organizations may have declined their research activities after independence, considering that during the colonial period most of them were quasi-governmental and were financed by general government revenues (Anderson et al. 1988).

Multinational companies do much less research in Africa than in Asia or Latin America. The only company with active plantation research in Africa seems to be Unilever, which undertakes oilpalm research in Cameroon and Zaire and tea research in Kenya. In Kenya BAT Industries conducts some applied research on tobacco and reforestation, and Del Monte has some research on pineapples. In addition, during the past five years, Pioneer began conducting maize research in Côte d'Ivoire.

The activities of multinational companies are multilevelled. They supply inputs such as fertilizers, pesticides and herbicides, animal health inputs, seeds and farm machinery and equipment. Moreover, multinational companies have long-standing interests in particular tropical crops, being either agricultural producers and managers of their own plantations, or

[19] This discussion focuses on the sub-Saharan region, it excludes North Africa.

increasingly, through contract farming. This option is an obvious one for a processing company that does not want to opt for vertical integration. Examples of this are: British American Tobacco in Kenya, Lonrho and Unilever.

At the other extreme, integration can go the full distance, from input supply to company estates, whose produce is processed and marketed by a single company. The examples of Nestle in Ivory Coast and Unilever in Ghana, Zaire, Nigeria, Kenya and Ivory Coast show how the multinationals spread across all sectors, introducing capital intensive technologies and devoting resources to research in order to maximize the sources for certain commodities and increase the market for manufactured goods and technical expertise.

Several multinationals have plantations in Africa. These include Booker Tate, which has interests in about 35 estates, mostly in sugar. The scale of these ventures can be considerable. Finchaa Sugar Project in Ethiopia, is perhaps the largest, involving an investment of about US$500 million. Unilever has its own plantations in some African countries involving extensive production of palm kernels, palm oil, sunflower, and fats.

Little is known about research by local companies in Africa, but the presumption is that it is very scarce. Local maize breeding in Zimbabwe has been successful. About half of Zimbabwe's total agricultural research budget is financed and performed by commodity organizations (Billing 1985). In Kenya most private research seems to be by multinational corporations and their affiliates. There are also strong research programs by the tea and coffee producer organizations. Commodity organizations undertake considerable research in francophone Africa — especially in Côte d'Ivoire.

There is a considerable level of commercial private sector activity in the seed industry where the general picture is of one national seed company per country - either public or private - with very little competition. Private companies appear to have made a considerable contribution to the development of agriculture in the countries in which they have worked. For example, the Kenya Seed Company is usually given credit for the considerable diffusion of Kitale hybrid and Katumani composite maize seeds in Kenya. Whereas public-sector organizations tend to be weak in promotional activities, the Company has solicited small outlets by offering a range of flexible incentives, including credit terms, attractive margins and the return of unsold stocks.

The Kenya Seed Company still operates like a private, profit-seeking company, but it does so with the consent of the majority shareholder, which is the Government of Kenya. Nevertheless this company undertakes quite extensive research activities spending approximately US$50 thousand per year in plant breeding for hybrid maize, sunflower, sorghum and pasture grass, as well as in seed, purity and germination. The situation in Zimbabwe is similar, in that the "private" Seed-Coop operates with a near monopoly and is subject to government control. It is regarded as an efficient organization and has succeeded in spreading improved maize varieties to the communal areas very rapidly. It is by far the largest seed company in the country and is responsible for almost all of maize seed sales, a majority of which are to small farmers in the communal areas. In the commercial sector, there is some competition, with Pioneer supplying most of the maize seed not accounted for by the Seed-Coop.

Although not so many local companies have facilities to fund and to undertake research, there is strong evidence of increasing research mostly due to the need to develop substitutes for imports. Strong evidence of this can be seen in the case of Kenya Breweries, a successful local company, that was compeled to develop a domestic source of malting barley.

There are some examples of nationally based foundations that undertake extensive research in Africa. The Coffee Research Foundation in Kenya conducts research on agro-chemicals, plant breeding and seed distribution, plant nutrition, processing and liquoring, and entomology. Another successful example is the Tea Research Foundation of Kenya. It involves 20-30 scientists and technicians who are engaged in research of several problems related to tea, including the productivity, quality and suitability of land in relation to tea planting.

A broad range of indigenous non-commercial organizations, such as coops, and community and church groups, are also involved in the seed sector, and these are often supported by foreign and local NGOs, such as the Zimbabwe Seeds Action Network. In the Gambia, seed distribution has been added to the responsibilities of NGOs involved in agricultural work, such as Action Aid, Catholic Relief Services, Save the Children Fund and the Freedom from Hunger Campaign.

Farrington and Biggs (1990) suggest that NGOs in Africa have sought to address the technology gaps left by the government research and extension services. For instance, the provision of high quality seed for resource-poor small farmers is an important focus where the NGOs are well positioned to conduct on-farm research and promote institution innovations. In francophone countries (Senegal particularly) NGOs have stepped in as economic recovery programs have reduced public sector extension services. In the Gambia NGOs are collaborating with the government in on-farm trials and in seed production. They are involved in extension and seed supply in Ethiopia and the Sudan, and in Kenya and Zimbabwe large numbers of NGOs focus on agroforestry, ecological agriculture and the promotion of small farmer organizations. NGOs based in more-developed countries may fund partner organizations in developing countries, such as Oxfam, or they may work through local offices, such Action Aid.

Table 4. A tentative list of private-sector multinational and local organizations that conduct and/or fund agricultural research in Latin America, 1991

MULTINATIONALS	COUNTRY	PRODUCTION AND RESEARCH ACTIVITIES	SOURCE
ACI	Bolivia	miscellaneous research, transfer of technology and training activities	16
Agchem/ Sanidad Vegetal	Venezuela	production of agrochemicals; conducts various adaptive research and field demonstrations	6
Anderson Clayton	Brazil, Mexico	soybean production; soybean research and development	51
Andre	Brazil	seed production; soybean production; research?	51
Asgrow Seed Company-Upjohn Company	Mexico, Brazil Venezuela Argentina	basic and applied breeding and crop improvement; also multiplication and distribution; in Brazil, it maintains breeding research station for tomato and short-day onions	1, 2, 15
Atar	Argentina	maize-hybrid production; research?	30
BASF	Brazil	conducts research in agrochemical inputs	8
Bayer	Chile, Brazil	miscellaneous adaptive research?	21, 51
British American Tobacco	Brazil	research?	51
Bunge	Brazil	seed production; soybean production and some research	51
CARE	Bolivia	conducts various research, transfer of technology and training activities	16
Cargill	Argentina Chile Mexico Brazil	in Argentina and Brazil conducts maize hybrids related research and multiplication and distribution of certified maize seed. In Brazil engages in animal production and animal breeding; animal feed production; soybean production and processing; citrus production and processing. In Chile, conducts variety testing	15, 30
CARITAS	Bolivia	conducts various research, transfer of technology and training activities	16
Carmex	Mexico	multiplication and distribution of certified maize seed; research?	15
Carribean Basin Investment Corporation-USA / Agro Inversiones C.por A.	Dominican Republic	fruit and vegetable production; conducts mostly adaptive research on new technologies and improved varieties	34
Central Soja	Brazil Puerto Rico Trinidad Jamaica	production of seeds, refined oils, poultry, food, feed, soybean processing; research?	37
Ciba-Geigy Ciba-Geigy Mexicana	Colombia, Brazil Chile, Argentina Mexico	formulation of agrochemicals; conducts research in chemical inputs, efficacy and safety testing; engaged in multiplication and distribution of certified maize seed in Mexico	6, 8, 15
CMIC	Bolivia	conducts various research, transfer of technology and training activities	16
Consorcio Agro Industrial de Malloa S.A.	Chile	fruit and vegetable canning; conducts various testing of cultivars in terms of yields, disease resistance and processing quality	2
Continental	Argentina, Brazil	production of hybrid-maize, in Brazil also soybean; research?	30, 51
CRS	Bolivia	conducts various research, transfer of technology and training activities	16
Cyanamid	Brazil, Argentina Mexico, Costa Rica Colombia Venezuela Dominican Republic	undertakes research activities of crop protection, animal nutrition and health-related chemicals	7
Dekalb-Pfizer	Mexico Argentina, Chile Brazil Nicaragua	basic and applied breeding and crop improvement; also multiplication and distribution of seeds mostly, hybrid maize, sorghum and sunflower; in Chile conducts variety testing while in Brazil conduct/research on agro-chemicals	8, 15, 21, 37

MULTINATIONALS	COUNTRY	PRODUCTION AND RESEARCH ACTIVITIES	SOURCE
Del Monte / Productos del Monte	Mexico	food processing and canning; conducts adaptive research of improved practices of crop production	49
Dreyfus	Brazil	soybean production and development	51
DESEC	Bolivia	conducts various research, transfer of technology and training activities	16
Du Pont	Chile	research?	21
FCH	Bolivia	conducts various research, transfer of technology and training activities	16
Firestone	Brazil	research?	51
Hanover Brands / Alimentos Congelados Monte Bello, S.A. (ALCOSA)	Guatemala	purchase and freezing of vegetables; operates 3 applied research sites; provides technical assistance for improvement of cultivation patterns	43
Harris Moran Seed Company	Mexico Costa Rica Brazil	seed production; operates research stations for melons and squash breeding, variety trials and testing of new hybrids; various biotechnology activities in Brazil	2
Hoeschst	Brazil, Chile	in Brazil conducts research in chemical inputs	8, 21, 51
ICI	Brazil	research in chemical inputs	8
John Deere & Company	Argentina Brazil, Mexico	production of agricultural machinery; some adaptive research	32
Limagrain Dinamilho (Limagrain)	Chile Brazil	operates two research stations related to maize hybrid development and introduction of new maize varieties	2, 9, 10
Nestle	Mexico	provides transfer of technology and some adaptive research	52
Northrup-King / Sandoz Ltd.	Mexico Argentina Brazil Venezuela	basic and applied plant breeding; in Argentina mostly related to wheat; also multiplication and distribution of seeds	2, 15, 30, 51
Petoseed / Peto Chile Petoseed de Baja	Chile Mexico	conducts breeding of new varieties of tomato and other vegetable seeds; breeding of new vegetable and fruit seeds varieties	2
Pioneer	Mexico Chile Argentina Brazil	basic and applied breeding and crop improvement. In Mexico engages in development of sub-tropical maize hybrid for mid to high elevations; in Brazil develops hybrids with tolerance to foliar diseases and aluminum toxicity, and in Argentina, conducts research on maize, sunflowers and sorghum	10, 15, 33, 51
Pittman Moore	Mexico	conducts research in animal nutrition products	52
Rommie-Haas	Argentina	agrochemical production; conducts program on hybridization of wheat	30
Semillas Agricolas Mexicanas	Mexico	multiplication and distribution of certified maize seed; research?	15
Semillas WAC de Mexico	Mexico	multiplication and distribution of certified maize seed; research?	15
Shell	Chile, Brazil	research?	21, 51
Sunseeds/Arco Seeds	Chile	production of tomato, onion and pepper seeds; research?	2
Tate & Lyle	Brazil, Belize	agribusiness, sugar production and refining; research?	37
Texas Golf/Soquimich	Chile	funds fertilizer related research undertaken by INIA	14
Unilever Gessy Lever	Brazil	conducts palm oil research	51
Upjohn	Puerto Rico Argentina Venezuela Guatemala Mexico	production of pharmaceuticals, chemicals, seeds and agricultural specialties; research?	37
Warner	Mexico	seed production; research?	52

LOCAL ORGANIZATIONS	COUNTRY	PRODUCTION AND RESEARCH ACTIVITIES	SOURCE
AHA	Argentina	association of cotton spinning mills; funds research project undertaken by INTA related to development of cotton cultivation techniques and production of cotton seed	28
ARGATOM S.A.	Argentina	funds research project undertaken by INTA on conservation of meat for a long period under ambient temperature	38
Asociaciones de Cooperativas Argentinas	Argentina	conducts wheat related research for development of new varieties	22
ATAR	Argentina	seed production; research?	30
CIBBIA	Argentina	cooperates and funds research project undertaken by INTA on conservation and micromanipulation of embryos and oocytes	38
COMEGA	Argentina	seed production; research?	29, 30
Crawford Keen	Argentina	seed production; conducts mostly adaptive research	30
CREA	Argentina	association of multi-products farmers; generation and transfer of technology	40
Criadero Klein	Argentina	wheat production; conducts research in wheat seeds	30
Criadero Thomas	Argentina	conducts wheat related research for development of new hybrid varieties	22
Criadero y Semillero "La Holandesa"	Argentina	maize production; research?	30
DESATEC S.A.	Argentina	cooperates and funds research project undertaken by INTA for development of viral insecticides	38
FAA	Argentina	cooperates and funds projects related to maize-hybrids undertaken by INTA	38
Fiplasto Forestal SA	Argentina	research center within industrial company; conducts forestry related research	3
INDUSTRIAS METALURGICAS MAIPU S.A.	Argentina	cooperates and funds projects undertaken by INTA on development of experimental prototype and commercial model of equipment for application of pesticides in horticulture	38
Instituto San Jorge-Bago S.A.	Argentina	cooperation with INTA and funding for developing vaccines	27, 38
La Serenisana	Argentina	conducts various research; also provides technical assistance to the farmers	44
Morgan (Santa Ursula)	Argentina	production of hybrid maize, hybrid sunflower and sorghum hybrid; conducts various research related to the above crops	30
Osvaldo Caldero y Cia (Manantiales)	Argentina	production of hybrid maize, soya, sorghum hybrid; research?	30
Palaversich y Cia S.A.	Argentina	production of soya, sunflower hybrid, sorghum hybrid; conduct mostly adaptive research in soybeans	30
PRODUSEM	Argentina	Cooperates and funds projects undertaken by INTA related to wheat cultivation	38
SANCOR	Argentina	agroindustrial complex; conducts various, mostly adaptive research activities in dairy, cooperates in and funds projects undertaken by INTA related to cultivation of fodder; also provides technical assistance to farmers	23, 44
SCYT/BIOTICA S.A.	Argentina	cooperates and funds projects undertaken by INTA related to production of pre-basic material of potato seed	28
S.LORENZO S.C.	Argentina	cooperates and funds project undertaken by INTA related to harvesting of cotton	28
S.P.S.	Argentina	seed production; hybrid sunflower production; research?	30

LOCAL ORGANIZATIONS	COUNTRY	PRODUCTION AND RESEARCH ACTIVITIES	SOURCE
Hershey Food Corporation	Belize	operates demonstration farm for production, fermentation and drying of cocoa, it is also used like nursery for improved varieties of cocoa seedlings; introduction of new seedlings and production and processing methods	43
C.C.B.	Bolivia	engaged in training, formation and technical supervision	16
Centro de Investigaciones Fitoecogeneticas	Bolivia	research related to selection of new varieties of various seeds, testing of their resistance, incorporation into local conditions and production of basic seeds of maize, wheat, beans	36
CORACA	Bolivia	provides training and formation activities and technical assistance	16
CUTCB	Bolivia	engaged in training and technical assistance	16
Plan Padrinos	Bolivia	conducts various transfer of technology and training activities; some very adaptive research	16
SBP	Bolivia	provides technical supervision	16
Servicios Múltiples de Tecnologías Apropriadas (SEMTA)	Bolivia	conducts various investigations related to all aspects of agricultural and livestock production	36
Agrale	Brazil	production of agricultural machinery; conducts research in agricultural machinery	8
Anhanguera	Brazil	feed production; research?	51
Avisco	Brazil	feed production; research?	51
CEPLAC	Brazil	cacao research organization; conducts research in all issues related to cacao	42
Companhia Brasileira de Tratores	Brazil	production of agricultural machinery; conducts research in agricultural machinery	8
Contibrasil	Brazil	conducts maize seed research	13
Cooperativa Agricola de Cotia	Brazil	agricultural multi-commodity cooperative; funds research in seeds	9
COPERSUCAR - Centro de Tecnología	Brazil	sugar cooperative; conducts research in all areas related to sugar-cane, sugar production, alcohol and its sub-products and co-products; also, transfer of technology to the associated agroindustrial enterprises through basic engineering and technical assistance	3, 8
Dinamilho	Brazil	conducts maize seed research	9
Dutra	Brazil	feed production; research?	51
Federacao das Cooperativas da Trigo e Soja no Brasil (FECOTRIGO)	Brazil	federation of wheat and soya cooperatives; conducts research in wheat and soybeans	9, 29
Francisco Terazawa	Brazil	conducts millet related research	10
HEK Continentes Comercio Ltda.,	Brazil	provides technical and agricultural assistance in: soil, preparation, sowing, harvesting and storage	2
Instituto Riograndense do Arroz	Brazil	conducts various research related to rice seeds	10
INTISOJA	Brazil	funds soya research and development	51
Jacto S.A.	Brazil	conducts research on harvesting machinery for coffee	8
JL Associates	Brazil	technical assistance on agriculture, including irrigation, soil conservation, mechanization; livestock and pasture management and development; agroindustry and land evaluation	31
Lapa	Brazil	feed production; research?	51
Organizacao das Cooperativas do Parana (OCEPAR)	Brazil	cooperative organization; wheat and soja production; conducts research in seeds	10, 29
Purina	Brazil	feed production; research??	51

LOCAL ORGANIZATIONS	COUNTRY	PRODUCTION AND RESEARCH ACTIVITIES	SOURCE
Reis de Ouro	Brazil	seed production, conducts maize seed related research	10
Sec. Agric.?	Brazil	hybrid maize production; research?	51
Sementes Agroceres	Brazil	seed production; engages in hybrid maize research; also technology transfer and adaptive research on hybrids cultivars; recently expanded its activity in herbicides, layer equipment, horticulture seeds and tissue culture research	8, 9, 13
Sementes Dois Marcos Ltda.	Brazil	funds research undertaken by Francisco Terazawa	8
Sementes Mogiana	Brazil	seed production; conducts seed related research	9
Top-Seed	Brazil	production of horticultural seeds; research?	9, 10
A.C. Baldrich	Chile	conducts research in various seeds	47
AGRARIA	Chile	non-government organization; conducts on-farm research	4
Agrarian Rersearch Group	Chile	non-government organization; on-farm and extension research related to various issues linked to the crop production, demonstrations, on-farm experiments, training programs	4
ANASAC	Chile	conducts variety testing of wheat, forage and maize; funds research undertaken by INIA	14
ANAGRA	Chile	cooperates with INIA in plant breeding of raps, calza and canola	14
Anilquimica S.A.	Chile	research?	21
Berries La Union C.P.A.	Chile	production of blueberries, gooseberries, boysenberries and raspberries; research?	2
CET	Chile	non-government organization; maintains small research and demonstration plots where self-sustained cropping and farming systems are designed and tested experimentally; also in other issues related to organic agriculture and agroecology	4
CIAL	Chile	non-government organization; maintains small research and demonstration plots where self-sustained cropping and farming systems are designed and tested experimentally; also in other issues related to organic agriculture and agroecology	4
Compañía Cervecerías Unidas S.A.	Chile	funds research undertaken by INIA for developing of new barley varieties, as well as in other areas of beer production	5, 14
Fundación Chile	Chile	technology transfer and assistance, undertakes feasibility studies; new product development; food quality control; microbiological, physical, chemical and pesticide residue analysis	19, 35
INDUS	Chile	rice research	39
Luchetti	Chile	funds research in durum wheat conducted by INIA	14
National Farmer's Association	Chile	conducts research related to genetically improved seeds of wheat, maize, dry legumes, barley, lentils, chickpeas and horsebeans; potato seed multiplication	47
Semillas Baer	Chile	conducts research in wheat, lupine, barley, rye, triticale, rape-seed and forage crops; also limited research on crop management practices	47
Sociedad Nacional de Agricultura	Chile	conducts plant breeding research mostly on wheat	39
Tehmko	Chile	funds fertilizer related research conducted by INIA	14
Asociación Colombiana de Productores de Flores (ASOCOLFLORES)	Colombia	flowers producer association, adaptive research, variety selection and disease resistance	41
Centro Nacional de la Caña (CENICAÑA)	Colombia	sugar cane research	18
Centro Nacional de Investigación de la Palma (CENIPALMA)	Colombia	oilpalm research institute funded by producer association	26

LOCAL ORGANIZATIONS	COUNTRY	PRODUCTION AND RESEARCH ACTIVITIES	SOURCE
Centro Nacional de Investigación del Café (CENICAFE)	Colombia	coffee research institute funded by coffee producers association; conducts research on ecological, agronomical and economical aspects of coffee production and processing	11, 42
Corporación de Estudios Ganaderos y Agrícolas (CEGA)	Colombia	technical assistance and some research in crops and livestock	26
Empresa Colombiana de Productos Veterinarios (VECOL)	Colombia	pharmaceutical production and some veterinary research	26
Federación Nacional de Arroceros (FEDEARROZ)	Colombia	rice association of producers; rice research	17, 42
Federación Nacional de Cultivadores de Cereales (FENALCE)	Colombia	producer association; research on sorghum maize wheat, oats, and barley	26
Institute of Technological Research	Colombia	research in cereals, farm machinery, fruits, pastures, etc	18
National Corporation of Forest Research and Fomentation	Colombia	research in biotechnology, crops and forestry	18
Semillano	Colombia	production of rice and tropical pasture seeds; plant breeding research since 1985	20
Semivalle	Colombia	joint venture with pioneer seed company; miscellaneous seed adaptive research activities	20
Fundación Dominicana de Investigación Agropecuaria	Dominican Republic	foundation; funds agricultural research	44
MANICERA	Dominican Republic	funds research in african oil-palm	24
Centro Andino de Acción Popular (CAAP)	Ecuador	non-government organization; conducts on-farm research and development of new agricultural technology	48
Centro Ecuatoriano de Servicios Agrícolas (CESA)	Ecuador	non-government organization; conducts various on-farm research and development of new agricultural technology	48
Fundación Ecuatoria para el Progreso Popular (FEPP)	Ecuador	non-government organization; conducts on-farm research and development of new agricultural technology	48
FUNDAGRO	Ecuador	research foundation; conducts and funds agricultural research	44
Cristiani-Burkard	Guatemala	maize seed production; conducts various maize research	15
Seminal	Guatemala	various seed research	15
Superb	Guatemala	seed marketing; has a joint research program with TACSA (a Mexican company) in maize seeds	15
Fundación Hondureña de Investigación Agropecuaria (FHIA)	Honduras	private research foundation; conducts applied research on citrus, cocoa, banana, vegetables, soybean and other tropical crops; also, soil and plant tissue analysis and pesticide residue analysis	3, 44
Alpart Farms / subsidiary of Alumina Partners of Jamaica Ltd.	Jamaica	carries out projects in land rehabilitation, land resettlement, cattle feedlot, dairy farms; conducts research, particularly related to the use of local agricultural by-products for livestock feeds	50
Sugar Industry Research Institute	Jamaica	developing of new technologies for sugar industry; technology transfer to sugar cane growers	3
Biogenetica de Mexico	Mexico	research in tissue culture, primarily with ornamentals	52
Bioquimix	Mexico	biotechnological research, mostly extraction of pigments from flowers	52
Cattlemen's Association of Tabasco	Mexico	technology transfer and some adaptive research activities	52
Ceres Int. de Semillas	Mexico	basic and applied plant breeding; crop improvement	15

LOCAL ORGANIZATIONS	COUNTRY	PRODUCTION AND RESEARCH ACTIVITIES	SOURCE
Patronato para la Investigación Pecuaria en Mexico	Mexico	non-profit organization; funds various agricultural research	52
Patronato de Sonora	Mexico	multicommodity farmer's organization; funds various research activities, mostly wheat	44
Semillas Tacsa	Mexico	basic and applied breeding and crop improvement	15
National Cotton Fund	Peru	cotton producer's organization; funds cotton research	44
National Maize Committee	Peru	farmer's organization; funds research in maize	44
Agromax SA (Hiperfosfato)	Uruguay	research center within industrial company; conducts research in fertilizers for crops and pastures	3
Asociación de Productores de Arroz	Uruguay	funds rice research conducted by INIA	45
Asociación Nacional de Productores Semillas (ANAPROSE)	Uruguay	association of seed producer Cooperatives; funds research in food commodities and seed technology services assisted by La Estanzuela Experiment Station (INIA)	45
Asociación Rural de Río Negro	Uruguay	funds research in agreement with INIA related to evaluation and adaptation of crops and pasture system	45
Asociación de Criadores de Hereford	Uruguay	funds animal breeding research conducted in collaboration with INIA	45
CALFORU	Uruguay	agroindustrial cooperative which produces vegetable seeds; engages in agricultural technology transfer and funds agronomic research and plant selection conducted under assistance of 'Las Brujas" Experiment Station (INIA)	25, 45
CALNU	Uruguay	sugarcane cooperative; conducts sugarcane related research	42
Central de Granos y Semilleristas	Uruguay	agricultural cooperative; engages in technology transfer and funds agricultural research	25
Central Lanera y de Carne	Uruguay	agricultural cooperative; engages in technology transfer	25
CETA	Uruguay	association of multi-products farmers; generation and transfer of technology	40
Cooperativa Nacional de Productores de Leche (CONAPROLE)	Uruguay	engaged in extension services to milk producers; funds research on pastures	25
Federación Uruguaya de Centros Regionales de Experimentación Agropecuaria (FUCREA)	Uruguay	engaged mostly in technology transfer for beef and sheep farmers; conducts on-farm research in cooperation with INIA's experimental stations	25, 45, 46
LATU	Uruguay	semi-private organization; research on quality of export products; funds research for improvement of the quality and suitability of vegetables and fruits to the agro-industry	45
SUL	Uruguay	Wool producers association; conducts wool research	42
FUNDESOL	Venezuela	research foundation; conducts mostly applied research	44
Fundación Servicio para el Agricultor (FUSAGRI)	Venezuela	foundation; conducts research in crop husbandry, plant protection - citrus, soybean, vegetables, rice, livestock husbandry and nutrition; veterinary medicine; also transfer of technology	3, 40, 44
POLAR	Venezuela	maize milling; owns experimental research station for development of new soybeans and maize varieties	44
PROTINAL	Venezuela	animal feed concern; conducts intensive research, including variety development for sorghum	44

Reference: Echeverría, R.G. 1992. Potential complementarities between public and private-sector agricultural research. ISNAR Working Paper No. ... The Hague: ISNAR.

NOTES - TABLE 4

1. This table reports very preliminary information gathered through a literature search. It represents a first step into a more thorough analysis. It is part of an ongoing ISNAR effort to examine the relationships between public- and private-sector research organizations.

2. Multinationals are arranged alphabetically by company name, country of headquarters in parenthesis.

3. Local organizations are arranged alphabetically by country name.

4. ? in "production and research activities" means reference is unclear or unknown.

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Table 5. A tentative list of private-sector multinational and local organizations that conduct and/or fund agricultural research in Asia, 1991

MULTINATIONALS	COUNTRY	PRODUCTION AND RESEARCH ACTIVITIES	SOURCE
Adam International	Thailand	production of oriental-type tobacco; conducts applied research for introduction of new tobacco varieties; also, adaptive research on sunflower seed variety; development of hybrid maize; field demonstrations of new agricultural techniques	16
Asgrow / Upjohn (USA)	Thailand Korea Indonesia	production of pharmaceuticals, chemicals, seeds research	21, 39
Atlantic Richfield Company / Dessert Seed Company	Thailand	import and production of vegetable seeds; research?	11
Bangkok Seed Industry Company Ltd.	Thailand	joint venture; maize seed operations for improvement of the quality of new maize hybrids; also anticipates in diversifying into hybrid sorghum, groundnut, and soybean seeds	11, 39
Bayer	Thailand Pakistan	in Thailand, conducts testing of the new compounds that have not been released commercially for their worldwide research program; also, research on the pesticide resistance problems of insects that attack cotton and vegetables	28
British Columbia-Thai Corp. Ltd.	Thailand	joint venture; shrimp enhancement project; the company provides hatchery, processing and training facilities, feed mills and market expertise	2
British American Tobacco	India Pakistan Indonesia Thailand Bangladesh Sri Lanka	agronomic research on reducing costs of flue-curing tobacco; in Bangladesh undertakes laboratory quality testing of its varieties; plant breeding; development of new varieties	25, 29, 30, 34, 39
Cargill	Thailand Indonesia India Philippines Korea Pakistan	maize seed operations for development of new maize-hybrids; in India undertakes plant breeding programs; in Thailand and Korea, testing of downy mildew resistant hybrid maize	6, 11, 13, 25, 27, 31, 34, 39
Charoen Pokphand (Thailand)	Thailand, Taiwan, Indonesia, Malaysia, Singapore, Hong Kong, China,	wide range of agribusiness activities: fertilizers, agrochemicals, pesticides and herbicides; tractors, animal feed, poultry and swine, crop farming and processing; various research activities; development of hybrids of maize, sunflower and sorghum; pig breeding and development of new hybrid-pigs	19, 39
Ciba-Geigy /Funk Seed (USA) Agro Seeds, Ltd.(Thailand)	Bangladesh Indonesia Malaysia India Thailand	research on improvement of application techniques and design of hand-sprayers for farmers; bio-efficacy trials of chemicals; in Indonesia conducts applied research and testing of new compounds on lowland rice; also plant protection research; in India, undertakes various plant breeding programs; in Thailand, Agro Seeds is specialized for research and evaluation of hybrid maize and sorghum seeds	6, 13, 25, 27, 30, 31, 39,
Continental Grain /Pacific Seed Co.(Australia) Pacific Seed (Thai) Ltd.	Thailand	research on hybrid maize and sorghum	6, 11, 25, 39
CPC International / Rafhan Maize Products	Pakistan	maize production and processing; various maize research and breeding activities; also provides extension services	10, 25, 34
Crompton Greaves, Ltd.	India	conducts research for quality improvement of irrigation pumps	31
Cyanamid	Philippines India Taiwan Hong Kong Korea	in Philippines research for development and testing of crop protection, animal nutrition- and health-related chemicals	8

MULTINATIONALS	COUNTRY	PRODUCTION AND RESEARCH ACTIVITIES	SOURCE
Dekalb (USA)	India Thailand	research in maize hybrids; also sorghum, swine and poultry research; in India concentrates on plant breeding	6, 25, 28
Dole / Philippines, Inc.	Thailand Philippines	integrated shrimp hatchery and processing plant in Philippines where undertakes shrimp breeding; in Thailand, conducts widescale testing of drip irrigation systems	1, 28
Dow Chemicals	Indonesia	conducts research on active ingredients for insecticides	33
Dunlop Research Centre	Malaysia	conducts rubber-related research	14
Du Pont / Du Pont Far East Inc.	Indonesia India Thailand	testing miscellaneous chemical research activities	28, 31, 33
East-West Seed	Thailand Philippines	joint venture; production of vegetable seeds; research on vegetable seeds	12, 39
ESSO	Pakistan	fertilizer demonstrations and trials of new varieties of rice and wheat; operates soil testing laboratory	30
Exxon	Pakistan	conducts research for improvement of maize, wheat, rice and sugarcane varieties; recently, funds public-sector research	34
Goodyear	Indonesia	conducts rubber research-testing of new varieties, fertilizer requirements, plant protection and reduction of loses from pests	33
Harrison-Crossfield / Harrison & Crossfield Serdang Berhad	Malaysia	research in development of new rubber clones	14, 33
Heinz Company	Thailand	tomato sauce production; research?	1
Hoechst	Thailand	research on pesticide resistance problems of insects that attack cotton and vegetables	28
Imperial Chemical Industries (ICI)	Bangladesh India Malaysia Philippines Pakistan Thailand	fertilizer trials; improvement of application techniques and design and testing of electrodine sprayers; in Pakistan, conducts trials of different chemical formulations and pesticides for control of pink boll-worm; in Thailand, research on pesticide resistance problems of insects that attack cotton and vegetables	14, 25, 27, 28, 30, 34
Indo-American Hybrids	India	production of hybrids vegetable seeds; conducts plant breeding program	27, 32
International Plant Research Institute (USA)	Malaysia	established joint venture with Syme Darby to set up Asian Biotechnology Corp. to conduct biogenetic plant research	25
Land O'Lakes (USA)	Indonesia	technology transfer for dairy cattle	33
London-Sumatra	Indonesia	conducts palm-oil research, especially development of new oil-palms clones; also breeding, agronomy and plant protection research in rubber, cocoa and coconuts	33
Mitsubishi	Pakistan	conducts pesticides and other chemical formulations trials for control of pink boll-worm	34
Monsanto	Indonesia	conducts mostly applied research for development of more effective methods of using its chemicals	33
Nestle	Sri Lanka	marketing of dairy products; research?	21
P. T. Bright	Indonesia Thailand	research in maize-hybrids; in Indonesia in association with Dekalb-Pfizer-Genetics	5, 33
P.T. Mantrust	Indonesia	technology transfer for dairy cattle; research?	33
Petoseed / Wann Shiang	Taiwan	development and production of tomato seed; research?	2
Philip Morris / Premier Tobacco Company	Pakistan	conducts tobacco variety testing for yield and quality improvement; recently, also barley varietal research	34

MULTINATIONALS	COUNTRY	PRODUCTION AND RESEARCH ACTIVITIES	SOURCE
Pioneer	Thailand Indonesia Philippines India	maize seed operations and development of maize-hybrids; research for quality improvement of seeds; plant breeding;in India engages in research for development of white sorghum and millet hybrids, subtropical maize hybrids; in The Philippines and Thailand the research program concentrates on development of subtropical maize hybrids	6, 13, 15, 25, 27, 33
Sandoz	India Pakistan	conducts various plant breeding programs; in Pakistan chemical formulations and pesticide trials for control of pink boll-worm	13, 34
Shell / Shell Chemicals Co.	Philippines Thailand	development and implementation of various projects for use of modern rice varieties; in Thailand, research on pesticide resistance of insects that attack cotton and vegetables	28, 30
Sime Darby	Malaysia Thailand	agricultural conglomerate; confines to groundnut seed production; conducts tissue culture research on oilpalm in Malaysia	11, 28
Sluis and Groot (Nederland)	Thailand	seed research?	39
Smith-Cline	India	operates laboratory for development of vaccines against local virus strains and other diseases	25
Socfindo	Indonesia Malaysia	conducts various research-testing new varieties, fertilizer requirements, and reducing the loses of pests- in its tissue culture laboratory related to rubber, cocoa, oil-palm, coconuts	14, 33
Tate & Lyle	Hong Kong	agribusiness; sugar production and refining; research?	22
Unilever / Hindustan Lever Ltd. Unilever	India Malaysia Thailand	various agricultural activities; food production; animal husbandry; conducts extensive research related to the use of Indian raw materials in the development of new and improved products; biotechnological research oil-palm and coconut cloning; research on management techniques in oilpalm production, trials of oilpalm plantlets	17, 28, 29, 33
Uniroyal	Indonesia	conducts plantation research on rubber and oil-palm	33
Universal Agriculture Co.	Thailand	production of hybrid tomato seed; research?	39
LOCAL ORGANIZATIONS	**COUNTRY**	**PRODUCTION AND R & D ACTIVITIES**	**SOURCE**
Beauty Engineering Works	Bangladesh	research on design of new irrigation and post harvest equipment, new plows and seed drills	26
BRAC	Bangladesh	non-government organization; poultry programs and other agriculture research related development activities	9
Comilla Cooperative Karkhana	Bangladesh	research on design of new irrigation and post harvest equipment, new plows and seed drills	26
Ittafag Industrial Corporation	Bangladesh	research on design of new irrigation and post harvest equipment, new plows and seed drills	26
Mennonite Central Committee/NGO	Bangladesh	non-government organization; conducts various inter-disciplinary research activities; on-station and on-farm trials, varietal screening and testing, development of soybean processing and other technologies and their adaptation to farm conditions	7, 9
Milnars	Bangladesh	pump producer; research for improvement of the efficiency of the process of producing pumps based on German designs	26
National Agroseeds	Bangladesh	research (screening) of local radish varieties for identification of best yielding ones, trials on tomatoes, cauliflower and ladies finger	26
New Light Inventory	Bangladesh	research for design of new irrigation and post harvest equipment, new plows and seed drills	26
North Bengal Agricultural Workshop	Bangladesh	research for design of new irrigation and post harvest equipment, new plows and seed drills	26
Phenix-Poultry	Bangladesh	funds research on maize and poultry	26

LOCAL ORGANIZATIONS	COUNTRY	PRODUCTION AND RESEARCH ACTIVITIES	SOURCE
Proshika	Bangladesh	poultry programs and other agriculture research related development activities	9
Shilpi-Food	Bangladesh	funds soybean research programs	26
Sterling Companies / Tea Estates	Bangladesh	adaptive research on new technologies for improvement of tea quality	26
Sugarcane Research Institute	Bangladesh	research center within industrial company; research on high yielding and high sugar varieties resistent to insects and diseases; collection of new germ/plasm; development of appropriate pest and disease control methodology; development of a sugarcane leased cropping system for growers	3
Ahmedabad Textile Industry's Research Association	India	conducts research related to agricultural production and utilization of agricultural goods	31
Agricultural Tools Research Center	India	independent research center; conducts research for design and development of improved and scientific agricultural hand tools and implements for small and marginal farmers; development of appropriate alternative energy technologies	3
Ambika Seeds Corporation	India	seed-related research	36
Andhra Sugars Ltd.	India	some applied plant protection and agronomic research	31
Annalaxmi Seeds	India	seed-related research	36
Associated Agricultural Development Foundation	India	partially supported by Associated Exporters of Onions; conducts research on development of better export varieties of onions and storage and shipping facilities	25
Auora	India	production of hybrid seeds; conducts various breeding programs	27
Bharatiya Agro-Industries Foundation	India	non-government organization; research for dairy cattle improvement, also, research related to animal health, nutrition and utilization of by-products; engages in afforestation, and waste-land development	9, 38
Bombay Textile Research Association	India	cotton-related research	31
Chandulal J. Parikh	India	seed-related research	36
Coromandal Indang Products	India	seed-related research	36
Daftari Seeds Farms	India	seed-related research	36
DCM Mills	India	some applied plant protection and agronomic research	31
Eicher	India	research for improvement of the quality of the tractors and other equipment used with it	31
E.I.D. Parry	India	seed-related research	36
Escorts Tractors Ltd.	India	research for improvement of the quality of the tractors and the equipment that is used with it	31
Escorts Ltd	India	research for quality improvement of their tractors and the equipment that is used with it	31
Ganga Kaveri Seeds	India	seed-related research	36
Godrej	India	feed production; conducts research on animal nutrition	31
Golden Tobacco Co.	India	research related to tobacco production technology	31
Hindustan Cocoa Products	India	some research on cocoa production	31
Indian Fertilizer Producers Association	India	fertilizer demonstrations and adaptive research	30

LOCAL ORGANIZATIONS	COUNTRY	PRODUCTION AND RESEARCH ACTIVITIES	SOURCE
Indian Jute Industry's Research Association	India	jute-related research	31
Indian Pesticides Association	India	some adaptive research and pesticides demonstrations	30
Indian Plywood Industry's Research Association	India	forestry related research?	31
Indian Rubber Manufacturers Research Association	India	rubber related research	31
Indian Sugar Mills Association	India	research related to the process of sugar production	31
Indian Tobacco Company	India	research in tobacco related production technology	31
ITC	India	research in?	36
Jyoti	India	research for quality improvement of the irrigation pumps	31
Kalpatharu Hybrid Seeds	India	seed-related research	36
Kanchanganga Seed Co.	India	seeds-related research	36
Kirloskar Brothers Ltd.	India	research for quality improvement of the irrigation pumps	31
Maharashtra Hybrid Seeds Co.	India	production and distribution of seed; research on new seed varieties especially pearl millet hybrids	13, 35
Mahendra Hybrid Seeds Co.	India	production of hybrid seeds of cereals, vegetables and cotton; conducts its own breeding programs	27, 32
Mahindra & Mahindra Ltd.	India	research for improvement of the quality of tractors and equipment	31
Mahyco Seeds	India	hybrid seeds productions; conducts various breeding programs and development of hybrid corn, sorghum and pearl millet	31, 32
Messina Beej Pvt Ltd.	India	seed-related research	36
Motilal Pesticides (India) Pvt.	India	pesticide-related research	31
Nath Seeds Pvt Ltd.	India	production of cotton, cereals and vegetables hybrid seeds; cotton breeding program	27, 32
National Dairy Development Board	India	cooperative; conducts extensive breeding program using exotic, improved local and crossbred cattle and artificial insemination program; engineering research on new milk processing and distribution equipment	25
Navbharat Seeds Private Ltd.	India	seed-related research	36
New Nandi Seeds Corporation	India	research in cereals and vegetables seeds	36
Nimbkar Seeds Private Ltd.	India	production of cereals, vegetables and oil seeds, conducts research for development of hybrid corn, sorghum and pearl millet	31, 36
NOCIL	India	seed-related research	36
Nuziveedu Seeds Pvt Ltd.	India	seed-related research	36
Purna Seed Co-op Society	India	seed-related research	36
Quality Seeds	India	seed-related research	36
Rallis India, Ltd.	India	production of agrochemicals; conducts research in pesticides and fertilizers	31
Shakti Sugars	India	sugar-related research	36
Silk & Art Silk Mills Research Association	India	research related to agricultural production and utilization of the agricultural goods	31
Southern Planters Association	India	research related to plantation crops	31

LOCAL ORGANIZATIONS	COUNTRY	PRODUCTION AND RESEARCH ACTIVITIES	SOURCE
South India Textile Industry's Research Association	India	research related to agricultural production and utilization of the agricultural goods;	31
Suttons	India	production of vegetable seeds; conducts breeding programs	32
Tata Energy Research Institute	India	research in agricultural biotechnology	29
Tea Research Association	India	research related to tea production	31
Tractors & Farm Equipments Ltd.	India	research for improvement of the quality of tractors and equipment	31
United Planters' Association of Southern India	India	research association; research related to soil and water conservation; plant production-improving tea yield and quality of development of new varieties/clones of the crop; husbandry practices; plant protection measures	3
Vegetable Oil Mills Association	India	research in all issues related to vegetable oil production	29
Venkateshwara Hatcheries	India	livestock research; also development of vaccines; animal nutrition	31
Vijay Seeds Co. Private Ltd.	India	seed-related research	36
Voltas Limited Agro-Industrial Products Division ??	India	affiliate of Intermediate Technology Development Limited; conducts mostly applied research on windmills for pumping and agricultural applications	3
Wool Research Association	India	research related to wool production	31
Balai Penelitian Perkebunan Medan (Sumatra Planters Association Research Institute)	Indonesia	research center within industrial company; conducts research related to natural resources; soil science; plant production, and plant breeding and protection	3
Oil Palm Plantation	Indonesia	palm-oil research	23
Perum Sang Hyang Sri	Indonesia	production of high quality rice seed; research?	4
P.T. Umas Jaya Cassava Plantation	Indonesia	cassava related research	23
Malaysian Rubber Producers Association	Malaysia	natural rubber producer's association; funds rubber research conducted by Rubber Research Institute of Malaysia	14
Malaysian Palm Oil Producer's Association	Malaysia	crude palm-oil and palm kernel oil association; funds research in palm oil conducted by Palm Oil Research Institute of Malaysia	14
Rafhan Maize	Pakistan	maize milling and processing; maize breeding research	34
Jaffer Brothers	Pakistan	research on the production and processing of potato seeds	34
Pakistan Tobacco Board	Pakistan	conducts various research programs related to tobacco, also varietal trials in cooperation with tobacco companies	34
Shakkarganj Research Institute	Pakistan	sugarcane research, mostly to increase the yield per acre and the sucrose content of the cane	34
Sind Sugar Research Institute	Pakistan	primarily conducts trials of different sugarcane varieties, fertilizer recommendations and development of pest control program	34
Agricultural Investors, Inc.	Philippines	funds regional testing of coconut hybrids and cultivars	24
Davao Plantations/Davao Fruit Corporation?	Philippines	banana plantations; conducts/funds banana related research	29
Eden Farms/Eden Fruit and Vegetable Incorporated?	Philippines	intensive research in varietal development of various vegetable seeds	37
Firs Farmers Association, Inc.	Philippines	cooperates in the implementation and funding of the Action Program for caraboa development	24
Hijo Plantations Incorporated	Philippines	funds research conducted by Twin Rivers Research Center	3

LOCAL ORGANIZATIONS	COUNTRY	PRODUCTION AND RESEARCH ACTIVITIES	SOURCE
Kaneko Seed Company	Philippines	conducts research in development of new vegetable seeds varieties	37
NALCO	Philippines	assistance in tree breeding and pulping studies, plantation establishment, and agroforestry	24
Philippine Association of Flour Millers, Inc.	Philippines	funds research related to fertilizers and pesticides	24
Philippine Coconut Research and Development Foundation	Philippines	co-funds the Technopack Project	24
Philippine Swine Research and Development Foundation	Philippines	funds swine related research	24
PICOP	Philippines	assistance in tree breeding and pulping studies, plantation establishment, and agroforestry	24
San Miguel Corporation	Philippines	large agroindustrial conglomerate: beer, magnolia, feeds and livestock, agribusiness projects; conducts various research, among, development of high-yield hybrid corn seed	5, 18
Twin Rivers Research Center / Twin Rivers Plantation Incorporated	Philippines	various research activities, laboratory analysis and field services; primary objectives are development of appropriate production technology for export bananas, cacao, coconuts and vegetables and provision of technical expertise in the fields of crop protection, cultural management and plant nutrition	3
Victorias Milling Company Incorporated	Philippines	industrial company; conducts sugarcane breeding and selection; tillage; cropping concepts; pest and disease control; research in soils and fertilizers; irrigation and drainage; extension service; block farming; provides farm and crop management assistance	3
Arbor Acres	Thailand	poultry research	28
Asian Chemical Fertilizer Industry Co.	Thailand	introduction and distribution of basmati rice; small research investment in testing new seeds	39
Chia Kwang Seng	Thailand	import of vegetable seed; various research, breeding and multiplication activities	39
Chiamgmai Chaiwiwat Ricemill Co.	Thailand	rice milling; introduction and distribution of basmati rice; small research investment	39
Chiatai	Thailand	vegetable seed production; various research and breeding activities	39
Devaporn Agriculture/partnership with Sluis and Groot Ndl.	Thailand	production of hybrid tomato seed; research?	39
Khao Chaiya Porn	Thailand	rice milling; introduction and distribution of basmati rice; small research investment for multiplication and testing	39
Know-you Seed	Thailand	production of hybrid melon seeds? research?	39
Mamrong Rice Mill	Thailand	rice trading; multiplication and testing of imported maize hybrid seeds	39
Ralston-Purina	Thailand	research in feed technology	28
Siam Mati Company Ltd.	Thailand	introduction and distribution of basamati rice; small research investment in multiplication and testing	39
Thai Seeds	Thailand	production and distribution of maize hybrid seed, also sorghum and sunflower seeds; conducts research mostly to improve their maize varieties	39
Tia Seng Heng Huat	Thailand	import of vegetable seeds; conducts various research and breeding and multiplication activities	39
T.S.A. Co.	Thailand	production of hybrid tomato seed; research?	39

Reference: Echeverría, R.G. 1992. Potential complementarities between public and private-sector agricultural research. ISNAR Working Paper No. ... The Hague: ISNAR.

NOTES - TABLE 5

1. This table reports very preliminary information gathered through a literature search. It represents a first step into a more thorough analysis. It is part of an ongoing ISNAR effort to examine the relationships between public- and private-sector research organizations.

2. Multinationals are arranged alphabetically by company name, country of headquarters in parenthesis.

3. Local organizations are arranged alphabetically by country name.

4. ? in "production and research activities" means reference is unclear or unknown.

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Table 6. A tentative list of private-sector multinational and local organizations that conduct and/or fund agricultural in sub-Saharan Africa, 1991

MULTINATIONALS	COUNTRY	PRODUCTION AND RESEARCH ACTIVITIES	SOURCE
Agrimo Sud-Ouest S.A.	Ivory Coast	production and research in palm oil	19, 42
Bayer Pharmaceutical (Germany)	Tanzania	research on leaf spot in bananas	41
Bayer	Ivory Coast	funding of research on pesticides and herbicides	18
Booker Tale (UK)	Zimbabwe, Ethiopia, Kenya, Nigeria, Senegal, Somalia	about 35 plantations in several countries in SSA; management and expertise in sugar and other crops; feasibility studies, site surveys, soil advice, variety trials, cropping system trails; carried out Mumias sugar project in Kenya	26
British American Tobacco (UK)	Kenya, Zaire, Cameroon	tobacco, poultry breeding; research in tobacco in Malakisi (W. Kenya); training in crop rotation, soil conversion, proper use of fertilizers and pesticides, afforestation and energy conservation	23, 24, 26, 29
Brooke Bond Oxo (UK) (Subsidiary of Unilever)	Kenya, Malawi, Tanzania, Zimbabwe	tea, coffee, flowers, vegetables; sponsor of Kenya Tea Research Institute; research on plantations for tea and carnations in Kenya	23, 24, 29
Cadbury Schweppes (UK) / Cadbury Nigeria Ltd	Ghana, Nigeria, Cameroon, Zimbabwe	cocoa and food processing; research in Nigeria	4, 14
Cargill (USA)/National Seed Company of Malawi Ltd	Malawi	seed production; research in maize	11, 12
Ciba-Geigy	Ivory Coast	funding of pesticides and herbicides research	18
Dalgety (UK)	Liberia	rice development assistance	14, 41
Del Monte (USA) / Kenya Canners Ltd	Kenya	production of pineapples; research related to control of mealy bug, improvement of quality of new clones, development of agronomic technology	32
Firestone Rubber (USA) / Firestone Rubber Plantation Company, Liberia	Ghana, Liberia	rubber; in Liberia research on soils, plant breeding, pathology	3, 11
Lonrho Ltd (UK) Lonrho/East African Tannin Extract Co.	Kenya, Malawi, Zambia, Tanzania, Mauritius, Zimbabwe, Ghana, Ivory Coast, Mozambique Kenya	tea, sugar, coffee, timer, cotton; acacia, maize, wheat; research in higher-yielding monocultures, profit systems of multicultures; adaptive research in wattle trees, maize, wheat	36, 43
Nabisco (US)	Zaire	manufacturing of its own developed rice soya blend	14
Nestle (Switzerland) Nestle Capral Novalin Nestle Afrireco Nestle	Swaziland Ivory Coast Ivory Coast Ivory Coast	production of pineapples and instant coffee food and food processing research research in spices Research Institute conducting research in food and food processing	10, 14, 18
Novo Nordisk (Denmark)	Tanzania	research conducted together with Darbrew (a state-owned producer of kibuki) in development of kibuki powder and concentrates; investigation of production of nonalcoholic version of kibuki	9
Oil Crop Development Ltd (j.v. IFC, CDC, EAI)	Kenya	research in oil crops	4
Paanar	Zimbabwe	research in seeds	4, 12
Pioneer (USA)	Ivory Coast, Zimbabwe	mainly maize seed supply; research farm in Ivory Coast conducting hybrid maize breeding	7
Rhone Poulenc	Ivory Coast	funding of research on pesticides and herbicides	18

MULTINATIONALS	COUNTRY	PRODUCTION AND RESEARCH ACTIVITIES	SOURCE
Rural Investment Overseas	Tanzania, Ghana	technical assistance; managing agribusiness ventures, undertaking feasibility studies, enterprise planning, market surveys, assistance in produce marketing	37
Sentec/Limagrain	Kenya	research in cereals	4
Shell/Shell International Chemical Company Ltd	Nigeria	research in agrochemicals; applied research projects	43
SOFACO	Ivory Coast	research in pesticides	18
Tanwat/CDC	Tanzania	tannin-extract production, hybrid maize, wheat, dairying; research in maize and wheat for introduction of new varieties	11, 20
Tate & Lyle (UK)	Nigeria, Zimbabwe, Liberia, Ghana	production of sugar and katemfe; technical assistance, feasibility studies, soil surveys	39, 40
Texaco Agro-Industrial Ltd	Nigeria	cassava and gari estates; funds research in developing systems control for weeds and insects; applies new research findings	16, 18, 31
LOCAL ORGANIZATIONS	**COUNTRY**	**PRODUCTION AND RESEARCH ACTIVITIES**	**SOURCE**
Bolux Milling	Botswana	funds wheat research trials	28
The Rural Industries Innovation Center	Botswana	design and testing of agricultural implements and post-harvest machinery	28
Mission de Developpement des Cultures Vivrieres (MIDEVIV)	Cameroon	development and improvement of seeds and planting materials	1
Action Aid Gambia	Gambia	(NGO) trials on groundnut varieties, sorghum, cowpeas; advisory assistance services	21
Caritas	Gambia	(NGO) seed multiplication for local vegetables; advisory assistance for research programming	21
Catholic Relief Services	Gambia	(NGO) sesame and sunflower testing; operates research station and nursery to produce improved fruit tree seedlings and bud seeds; research in cowpeas	21
Freedom from Hunger Campaign	Gambia	(NGO) operates a rice production research unit focusing on multiplying improved varieties	21
Methodist Mission Agricultural Program	Gambia	(NGO) development of horticultural gardens, orchards, and fruit tree nurseries; environmental research; trials on living fences (euphoria)	21
Monktara Group	Gambia	horticultural research	22
Radville Farms	Gambia	small-scale horticultural research	22
Associations of Growers	Gambia	conducts some crop-related research (poultry, maize, livestock, sesame)	22
Cocoa Research Institute	Ghana	(semi-private) cocoa; cocoa-related research	5
Forest Products Research Institute	Ghana	(semi-private) forestry; forestry-related research	5, 13
Ghana Grains & Legumes	Ghana	maize and cowpea production and adaptive research	13
Ghana Seed Company	Ghana	(currently in receivership) conducts seed-related research	13
Leaf Development Co. Ltd	Ghana	tobacco; conducts research related to tobacco	19, 42
Nat. Oil Palm Plant Ltd	Ghana	palm-oil production and research	13
Timber Export & Dev. Board	Ghana	timber; research in pricing and marketing	13
Twifo Oil Palm Plant Ltd	Ghana	oil-palm plantation and palm-oil mill; conducts palm-oil-related research	13
Institut de Recherche de l'Huile et les Oleagineux	Ivory Coast	germinated seeds, palm oil and kernels; research in genetics, vegetative improvements, and agronomy	3

LOCAL ORGANIZATIONS	COUNTRY	PRODUCTION AND RESEARCH ACTIVITIES	SOURCE
Palmindustrie	Ivory Coast	oil-palm and coconut plantations with outgrowers; conducts palm-oil-related research	10, 18
Societe Africaine de Plantations d'Heveas	Ivory Coast	rubber production; funds rubber-related research	11, 18
Societe de Grand Beresy (SOGB)	Ivory Coast	funds rubber-related research	10, 18
Societe pour le Developpement des Plantations Forestieres	Ivory Coast	hardwood forestry plantations; research in forestry	11, 18
African Highlands Produce	Kenya	tea production; conducts research related to tea production	4, 23, 24
Coffee Research Foundation	Kenya	coffee; conducts research involving testing, recommendation of chemicals, breeding, nutrition, and entomology	4, 35, 29
Delamare Estates	Kenya	livestock; conducts livestock-related research	4, 23, 24
FMC Ltd	Kenya	conducts research in agrochemicals	4, 23, 24
Kenya Breweries	Kenya	research in testing and developing malt barley varieties	24
Kenya Cashew Nuts Ltd	Kenya	production and processing of nuts; conducts nut-related research	4, 15
Kenya Fruit Processors Ltd	Kenya	fruit processing; conducts some research related to fruit processing	4, 15
Kenya Jojoba Industries	Kenya	jojoba production; jojoba-related research	19, 42
Kenya Orchards Ltd	Kenya	production of flowers; conducts flower-related research	4, 15
Mumias Sugar Co. Ltd	Kenya	(partly owned by CDC) sugar estate and processing; provides technical assistance to outgrowers, including integration of food and cash crops	26, 43
National Irrigation Board	Kenya	funds research related to rice (variety selection, agronomy) and cotton	36
Nightingale Farms	Kenya	conducts poultry-related research	4, 23, 24
Pyrethrum Bureau	Kenya	(Research Center of Chemical Indust. Comp.) pyrethrum; conducts research involving analysis service, chemicals, instrumentation, and bioassay	3, 29
Tea Research Foundation	Kenya	conducts and funds research in problems related to tea planting and production	3, 17
Twiga Chemicals Ltd	Kenya	agrochemical production and research	4, 23
Wellcome Kenya Ltd	Kenya	conducts research related to pharmaceutical (livestock drugs and vaccines)	4, 23
Liberia Rubber Research Institute	Liberia	conducts rubber-related research	33
Impala Farming Co Ltd	Malawi	mixed farming; conducts tobacco-related research	11, 19, 42
Kawalazi Estate Co. Ltd	Malawi	(70% owned by CDC) conducts research in tea and coffee	11, 19, 42
Press (Holdings) Ltd	Malawi	production of tobacco and seeds; conducts research in tobacco	43
Tea Research Foundation of Central Africa	Malawi	tea research (irrigation, planting, soil and water conservation, breeding, bio-chemicals, pathology, and entomology)	3
Tobacco Research Institute	Malawi	(semi-private) conducts tobacco-related research	5
Office du Niger	Mali	(parastatal) operates a number of research stations, rice processing plants, cotton factory, sugar refineries and distillery; research on their related activities	1, 10
Agricultural Machinery Manufact. & Engineering Co.	Nigeria	conducts research in cassava processing technology	27
Agricultural Seeds Ltd	Nigeria	production of maize seeds; conducts maize breeding research	7
B&T Engineering Co.	Nigeria	conducts research in cassava processing technology	27
Cocoa Research Institute	Nigeria	(semi-private) conducts cocoa-related research	5

LOCAL ORGANIZATIONS	COUNTRY	PRODUCTION AND R&D ACTIVITIES	SOURCE
Nigerian Tobacco Co.	Nigeria	tobacco production and processing; research in variety selection	4
Rubber Research Institute	Nigeria	(semi-private) conducts rubber-related research	5
Sahara Engineering Co.	Nigeria	conducts research in cassava processing technology	27
Talon Ltd	Nigeria	food and fisheries production and research	2
Haggar Group Ltd	Sudan	tobacco, coffee, and tea production; tobacco-related research	30
Mhlume Sugar Co. Ltd	Swaziland	irrigation; sugarcane production and processing; conducts research in sugar	33, 38
Shiselweni Forestry Co. Ltd	Swaziland	pine and eucalyptus plantations; conducts research in variety selection	11, 41
East Usambara Tea Co. Ltd	Tanzania	tea estates redevelopment ?	11, 41
Farmlands Tanzania Ltd	Tanzania	tobacco and maize production and research	19, 43
Kwamtili Estate Ltd	Tanzania	cacao production and research	19, 43
Mafia Coconuts Ltd	Tanzania	coconut production and research	19, 43
National Coconut Development Program	Tanzania	training, disease and pest control, smallholder and plantation development; coconut breeding and agronomy trials	1
Rotian Seed Co.	Tanzania	vegetable seed production and research	19, 43
Tanganyika Tea Growers Assoc.	Tanzania	funds tea research	1
Office des Produites Agricoles du Togo (OPAT)	Togo	(parastatal) agricultural development; funds agricultural research	1, 10
Office National des Produits Vivriers (Togo Grain)	Togo	(parastatal) development of staple food crops	1, 10
Madhvani Industries	Uganda	sugar processing; conducts sugar-related research	33, 40
Tea Authority	Uganda	funds tea research	4
Lukanga Investment and Development Co. Ltd	Zambia	interest in number of crops; research in tobacco and maize	19, 42
Twiza Laboratories and Construction	Zambia	agroindustrials and chemicals; conducts research in pharmaceuticals and agricultural chemicals	3
Agricultural Development Authority	Zimbabwe	funds agricultural research	4
Agricultural Research Trust	Zimbabwe	funded by the Commercial Farmers Union; conducts agroeconomic research on two research farms; allocates 20% of resources to research	8
Coffee Growers Association	Zimbabwe	coffee production and distribution; funds research conducted by Department of Research and Specialist Services	8
Commercial Cattle Farmers Association	Zimbabwe	funds cattle research	4
Pig Industry Board	Zimbabwe	experimental farm conducts research for pig production	3
Rattray-Arnold Research Station	Zimbabwe	conducts research in maize breeding and variety testing	34
Tobacco Research Board	Zimbabwe	tobacco production and manufacturing; conducts tobacco research in agronomy, physiology, and pest and disease control	4, 8
Zimbabwe Seed Co-op Co.	Zimbabwe	seed production; conducts agroeconomic and plant breeding research; funds public-sector research	6, 25
Zimbabwe Sugar Association	Zimbabwe	sugar production and processing; funds and conducts research in plant breeding, agronomy, pathology, and entomology of sugarcane	8

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5. SUMMARY AND CONCLUSIONS

Most of the literature on technical change in agriculture has focused on public-sector research although agricultural technology is not produced only by government research institutes. Private-sector organizations, play an important role in generating and transferring new technologies. It must be emphasized that the distinction between public and private sector research is not clear-cut. This document examines the meaning of public and private to find that there is a complex, almost a continuum, of organizations conducting and/or funding agricultural research, which extends from government research institutes to private input and processing companies.

An organization may be classified as public or private according to: ownership and control, sources of funds, and economic behavior. Based on this the following organizations are classified as private sector - non-commercial: some aid agencies, foundations, and voluntary organizations; whereas the commercial private sector organizations are: farm sector organizations (farmers, cooperatives and producer organizations, plantations and estates, other large firms, commodity institutes); input industries (seeds, feeds, animal health products, agro-chemicals and fertilizers, farm machinery and equipment); and processing and food sector companies, consultancy and management companies.

The type of private organization that predominate in conducting and/or funding agricultural research varies considerably among countries. Despite the paucity of information on private research some generalizations are possible. Private research is located primarily in Latin America and Asia, and it is concentrated in a few large countries such as Brazil, Mexico, Argentina, and India. Research conducted by local companies seems to be more important in Asia than in Latin America. Private research expenditures in the seed and machinery industries is growing. Agricultural chemical research seems to be growing in Asia, but the evidence is less clear for less-developed countries as a whole. There are too few data on plantation and processing research to be confident about the trends. The amount of private food and agricultural research is low in low-income countries and generally grows with output per capita.

To understand the potential public-private interactions, it is important to focus on the type of research in which each sector is involved. That is basic, strategic, applied and adaptive research. A research process consists of several steps that should not be interpreted as independent stages but as part of a continuum from more basic to more applied activities. This sequence has to be extended further in order to link research to productivity growth, making the distinction between research to produce knowledge and research to develop technologies. Basic research is almost by definition a non-commercial activity. Uncertainty as to the probability of success, the nature of the output and its commercial applications has tended to make basic research the preserve of the public sector, and of private firms in high technology industries with great economies of scale and sufficient resources to make the investments necessary to pursue promising outcomes. Since the public sector has traditionally focused on basic research while the private sector has concentrated more on applied research, the comparison between public and private activities may not be pertinent.

An analysis of the reasons for public intervention in agricultural research shows that to maximize social welfare public intervention is necessary in cases where markets fail. The

private-sector will underinvest in research for three reasons: inappropriability, uncertainty and indivisibilites. In addition there is a range of further reasons for public intervention: preserving competition, complementarity with education, public goods, discounting the future, unemployed resources, intervention on distributional grounds, institutional innovation, support of policies and imperfect knowledge. These arguments stress the need for public intervention where there is a lack of markets, or where markets fail. In the shorter run this may call for public provision or the creation of a quasi-market. In the longer run, the public sector should aim to assist in the evolution of markets and other appropriate institutions, such as trade secrets laws and patents, which create markets. There are also arguments against public intervention. Market failure is a necessary but not a sufficient condition for government intervention.

There are cases that research must be conducted or supported by the public sector or it will probably not get done at all. This is a powerful argument for public intervention in the allocation of resources to research. The public sector must cover the basic end of the research continuum and if it should fail to do so, there will be no downstream private research and hence no productivity growth. In addition, public-sector institutions have a clear role to play in the generation and transfer of technology for small farmers and where market size or the type of technology presents a low prospect to recuperate research costs.

Three groups of factors influence the nature and the level of private agricultural research investments: (a) market factors, such as the expected growth in demand for agricultural products, derived demand for modern agricultural inputs, and factor prices facing farmers and agribusiness; (b) the ability of firms to appropriate the benefits from new technology; and (c) the technological opportunities for producing profitable products. Demand and factor- price issues play an important role in research investment decisions by private firms. The role of appropriability is revealed by the propensity of seed firms to concentrate their research efforts on breeding hybrids rather than open-pollinated varieties. Technological opportunity measured by patents, technology imports, and local public-sector research were found to have had positive impacts on the level of local research investment.

Appropriability is a function of the type of research and also of the area of technology. Private incentives are greatest in mechanical technology, followed by chemical, then biological, with managerial technology the least attractive investment. Private-sector incentives to conduct or fund research will be weak in: basic biology and physical research, generic research with broad application across commodities, for areas of technology where knowledge cannot easily be embodied in property produced, such as most agronomic research, and where the institutions to protect intellectual property rights are ineffective. In general private incentives are greatest in mechanical technology, followed by chemical, then biological, with agronomic technology the least attractive investment.

The boundary between the public and private sectors vary according to area of research, the type of technology, the level of development and other factors. All else being equal, the private-sector should be relatively larger in economics where: there is open trade that fosters commercialization, and commercial development has not been stifled by regulation; the cultural endowments were amicable to the creation of institutions that encouraged commerce; and there has not been opposition to the market on ideological grounds. Institutional changes, that may take time, will be necessary for the evolution of a better balance between

public and private activities. In this sense, given the public-private complementarity arguments examined in this paper as well as the time lags involved for research to have an impact, the development of private-sector research could be consequence of earlier public-sector research efforts. This means that instead of simply assuming that both sectors research activities are substitutes, and attempt to reduce public research to increase private-sector research, the future advancement of private research may depend on present investments in public-sector research.

Clearly, privatization needs to be regarded in relation to specific types of research activities, and not as a panacea. This means that policy reform should be based on a proper estimation of the weaknesses of the public sector, considering that genuine reforms may not be easy to achieve. The essence of privatization is to promote competition but not in the substitution of parastatals by large scale private companies that could raise monopoly and regulatory problems. In the area of research and technology there is no case for a simplistic approach to liberalization or privatization.

The interaction between private- and public-sector research could take place through formal and informal channels. Formal links consist, among others, of contract research, consultantships, cooperative research projects, and joint ventures. Private companies may buy technical information for their research activities by hiring scientists from universities, government research programs and consulting firms. In addition private companies fund specific projects (or researchers) in universities or research institutes. There are, in general, many possibilities of collaboration at the research and commercialization levels and also at the policy level to develop intellectual property protection. The public and private sectors are also linked, formally and informally, in transferring technology when private companies market publicly developed technologies or when public extension systems transfer privately developed inputs.

The structure and efficiency of the public-private interaction is affected by the amount and type of public and private research being conducted as well as by how much government policies and regulations impede (or discriminate) or encourage private-sector participation. The policies and regulations which have most impact on the private sector are those concerned with: research permissions and approval of new technologies, conditions on multinational companies, property rights, trade and price regulations, and tax incentives for research. An improved public-private interaction will encourage cooperation to serve the public interest paying special attention to the fact that farmers' needs and market demand should have a significant input in the process of technology generation and transferring, rather than the other way round.

The private sector can collaborate with the public sector in several areas, such as: joint research, provide human, technical and financial resources necessary to insure implementation of a mutually beneficial research agenda, take the lead in carrying out and financing downstream activities, such as input supply, post-harvest and processing research, marketing and transferring of technology.

Governments have a number of policy instruments with which to influence private research. Public-sector research can foster private-sector research by providing (or selling) research results and by training the personnel needed by private companies to conduct research. The

development of intellectual property rights such as patents and plant variety protection laws, if they are well designed and enforced, can create the necessary incentives for private companies to invest in research.

In the absence of breeders' rights laws, seed firms will focus their research on hybrid crops because self-pollinated crops can be reproduced and sold in the absence of legal prohibitions, or enforcement of the laws. Patents strengthen property rights to new technology. They require the disclosure of a new technology to the public and also provide the basis for market links between companies that develop new technologies and those who only market them. In the absence of patents, companies protect their new technology through trade secrets which restrict the flow of technological information and may reduce the incentives to license the technology widely. Finally, technology imports can stimulate local research so more liberalized technological trade could also increase private-sector research activities.

More accurate data on private research expenditures and their impact and further research on potential public-private research interactions would help policymakers and public administrators identify the potential areas of conflict versus complementarities between public and private research endeavors. In addition, empirical studies of the impact of the various technology-policy instruments and of alternative public-private institutional arrangements for research could help policy-makers use them more effectively.

In the short term for the more-developed countries and in the medium term for the less-developed countries there is likely to be an accelerating trend toward privatizing agricultural research. Moreover, the nature of the technologies being developed in the public and private domain is also likely to undergo substantial change. Taken together, these changes will reshape the conduct of agricultural research in less-developed countries, the relationship between less- and more-developed country (public and private) research activities, and the policy agenda facing public agricultural research institutions.

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