AGRICULTURAL COMPETITIVENESS: MARKET FORCES AND POLICY CHOICE

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Public and Private R&D in Latin America and the Caribbean

Throughout the developing world, private-sector research is likely to increase substantially, giving rise to fundamental changes in agricultural research in the public sector. Public- and private-sector research organizations will need to institutionalize arrangements to allow complementary relationships and a rational division of labour to develop. In fact, the relationship between the public and private sectors has varied over time, depending on a combination of policy and technological factors. An understanding of both public and private agricultural research roles is a prerequisite for informed public policy choice on this matter.

This paper reports on a study at ISNAR which documents and analyses the roles of public- and private-sector organizations conducting or funding agricultural research in three Latin America and Caribbean countries. The relationship between the two sectors was examined, and the types of research conducted by each sector and their contribution to the research process were reviewed. The study reports on data obtained during surveys on Colombian, Ecuadorian and Jamaican research institutes that were undertaken in 1992 and 1993. Interviews were held with representatives from 37 selected private organizations as well as 11 public institutions engaged in research.

CONCEPTUAL FRAMEWORK AND DEFINITIONS

The present discussion attempts to be schematic rather than deterministic. It argues that there are some types of research and some types of technology where the public sector will have the responsibility because the private-sector alternative seems unlikely or undesirable. In other cases, it would seem wasteful for public-sector efforts to duplicate what is adequately provided by the private sector. The real debate takes place over the 'grey areas' where both public- and private-sector research have their logic, especially if their activities are seen as complementary rather than as substitutes for each other.

It is useful to think of the interaction among types of organization or the roles of public and private sectors within agricultural research in relation to the following factors:

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- The public to private sector continuum,
- the basic to adaptive research continuum,
- the continuum of 'non-appropriable' to 'appropriable' benefits according to the nature of the technology,
- the market size for research output or technology.

Adopting the typology of public and private organizations established by Thirtle and Echeverría (1994), the private sector includes commercial firms such as input companies, farm sector and food processing companies, as well as non-commercial organizations such as foundations and non-governmental organizations. At the other end of the scale, the public sector includes national

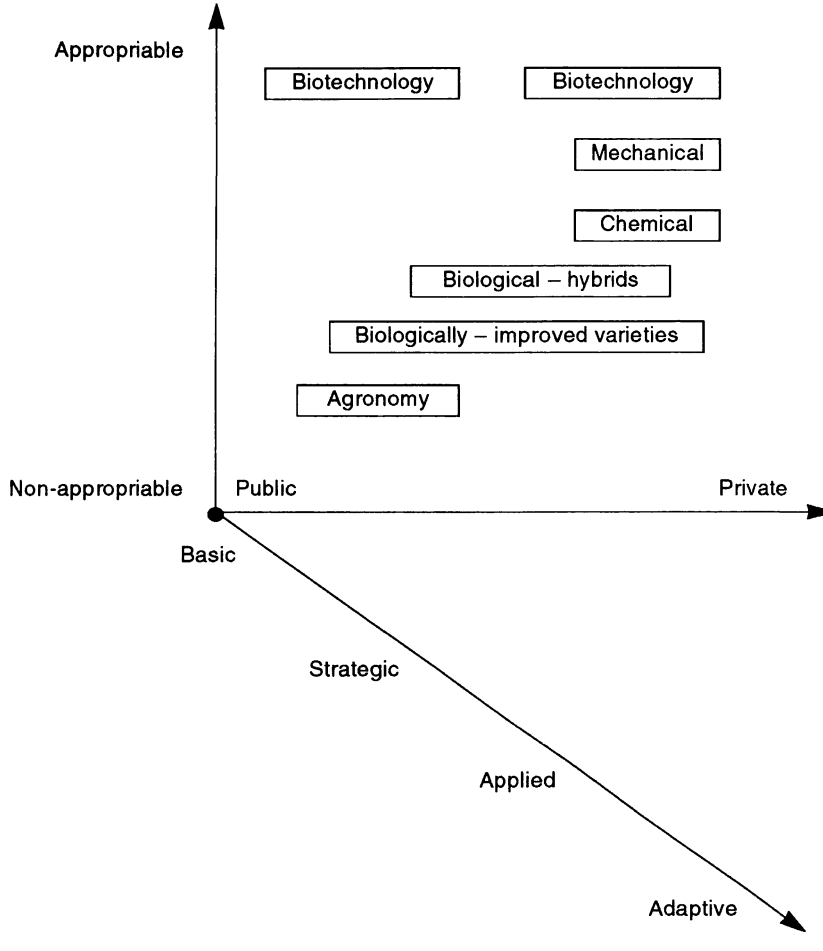

FIGURE 1 *Types of technology, appropriability and roles of the public and private sector*

institutes for agricultural research, universities, parastatals and IARCs. In this paper we use the polar extremes of 'public and private' to introduce expected behaviours, but it is clear that the definition of 'private' research is closely related to three things: (1) who appropriates the benefits of research (that is, the public or private nature of the technology produced); (2) who executes the research (related to the comparative advantages of the various actors); and (3) who pays for the research (which may be related to the goals that are sought)?

Following the Consultative Group on International Agricultural Research (CGIAR) definitions, research can be classified as basic, strategic, applied or adaptive.[1] The technology that is produced is classified as managerial/agronomic, biological, chemical, mechanical and 'others' (including biotechnology). These technologies may also be classified according to the degree to which the benefits of research can be appropriated by their originator. The degree to which research benefits are appropriable depends on a large number of factors, including the nature of technology, the nature of property rights, as embodied in patents or plant variety legislation, and asymmetries in the costs of replicating versus inventing new technologies. As illustrated in Figure 1, the private sector may be expected to concentrate on technologies where benefits are appropriable (such as mechanical and chemical), while the public sector is called to work on biological and managerial technologies where the non-exclusion of 'free-riders' makes it impossible for a private firm to appropriate the benefits.

Market size is an important determinant of the size of private-sector research investments. Even in the case of technologies where benefits are intrinsically appropriable, public investment in research may be necessary if the expected market is small. In other cases, if the expected market is sufficiently large to allow a firm to recover cost through the sale of embodied technologies, the private sector may be induced to invest in and carry out research. The private sector may even invest in (or execute) research where the technology is intrinsically non-appropriable and the market is small if the public sector induces it with policy incentives and mechanisms, or if early entry into a niche market creates market control.

PUBLIC- AND PRIVATE-SECTOR AGRICULTURAL RESEARCH

In this section, the main results of the survey conducted in Colombia, Ecuador and Jamaica will be presented. The survey sought information related to (1) the organization itself (operational structure, sale of products, market share); (2) research carried out (nature of research, type of technology, impact of research, personnel, expenditures, sources of funding, organizations supporting research, technology transfer, existing and potential relations with other components of the technological system); and (3) policy context and future direction of the organization (macroeconomic and sectorial policies, legislation and institutional changes affecting research investment, future activities such as investment or research-oriented work, interactions with public sector).

The public sector sample was composed of three national institutes, four universities, three parastatals and one regional centre. The private sector sample

consisted of two foundations, three non-governmental organizations, 12 growers' associations, five commodity boards and 15 private commercial organizations. In total, 11 public and 37 private organizations were interviewed across the three countries.

Level and growth of resources

The level and growth of several key agricultural research indicators for the public and private sectors are presented in Table 1. In the three countries, the private sector showed strong positive growth in research expenditures. This was significantly higher than growth in public-sector research expenditures. In Colombia, for example, private-sector research grew three times as fast as public-sector research.

Private-sector investments, expressed as a percentage of public-sector research expenditure, were (approximately) 40 per cent in Ecuador, 60 per cent in Colombia and 130 per cent in Jamaica. However, private-sector research expenditures in relation to the agricultural gross domestic product (giving a measure of the private-sector contribution to the agricultural research intensity ratio, ARI) remain low in Ecuador and Colombia. The ARI ratio in Jamaica is relatively high, as is characteristic of small countries (Ruttan, 1989; Eyzaguirre, 1994).

Turning to human resources, in all three countries the qualification index (that is, the percentage of researchers having completed a master's or doctoral degree) is higher in the private than in the public sector. However, the absolute number of professionals with post-graduate qualifications in the public sector is still higher than in the private sector. This may be attributed to the fact that the public sector must perform some upstream research (basic and strategic) that requires more specialized and qualified researchers. This is particularly the case in the Colombia.

Another important difference is found in the growth rates for professional staff. In all three cases the private sector showed higher growth rates than the public sector. In Ecuador and Jamaica, the private sector grew during 1985–92, while the most important public institutions of the agricultural technological system showed a decline in the number of its professionals (INIAP, Ecuador –2.2 per cent; Ministry of Agriculture Research and Development Division (MINAG), Jamaica –19 per cent). These data suggest that the private-sector efforts to improve and strengthen its research programmes are doing so by attracting public-sector researchers. Our survey revealed that a high percentage of the researchers holding key positions in private research programmes (for example, about 50 per cent of Colombian private researchers with post-graduate qualifications) had previously been employed and trained by the main public research institutes. The principal cause cited for this migration from public to private activity was the salary differential between the sectors. Private-sector salaries in Jamaica and Ecuador were three times greater than public-sector salaries. However, since research expenditures in the private sector do not appear to have risen as fast as numbers of researchers, one might question how long this trend can continue.

TABLE 1 *Public and private sectors: financial and human resources*

	Colombia		Ecuador		Jamaica	
	Public sector	Private sector	Public sector	Private sector	Public sector	Private sector
Annual growth rate research expenditure, per cent	2.3[a]	6.9[a]	–7.1[b]	1.0[b]	0.74[c]	1.4[c]
Research expenditure/ agricultural GDP, per cent	0.29[d]	0.17[d]	0.20[d]	0.08[d]	0.98[e]	1.26[e]
Private research/public research, per cent		59[d]		40[d]		128[e]
Private research/total research investment, per cent		38[d]		30[d]		56[e]
Human resources						
PhD	98	18	0	3	12	10
MSc	274	52	55	6	18	11
BSc	357	173	144	13	25	23
Total	729[f]	243[f]	199[d]	22[d]	55[e]	44[e]
Annual growth rate, per cent						
researchers	6.8[g]	13.8[g]	–2.2[b]	5.5[b]	0.7[c]	1.4[c]
technical/research staff	0.6[g]	1.5[g]	0.5[b]	1.0[b]	0.7[c]	1.2[c]
Real expenditure per researcher	7.1 m. pesos (1980–91)	12 m. pesos (1980–91)	1.8 m. sucres (1991)	6.1 m. sucres (1991)	0.2 m. JM dollars (1992)	0.6 m. JM dollars (1992)

Notes: [a]1970–91. [b]1986–91. [c]1985–92. [d]1991. [e]1992. [f]1989. [g]1980–89.

Source: Falconi (1993, 1994).

It was also observed that there was a difference in all three countries between the technical support to researcher ratio by sector. In Colombia, for example, a private-sector researcher was supported on average by almost three technical staff while in the public sector one technical support staff was shared by two researchers. This difference in technical support might imply that the efficiency and productivity of the public-sector researcher is lower than those of his counterpart in the private sector.

Although both sectors showed a negative or low annual growth rate in real expenditures per researcher during the period of analysis, the private sector, in all three countries, allocates at least twice the resources per researcher that the public sector does. In effect, private-sector researchers have more resources to carry out their work and a narrower research scope. Therefore they have better opportunities to generate accurate and quality research results than do their public-sector counterparts.

Sources and uses of funds

There are also important differences between the public and the private sector entities in the sources and the uses of their funds (Falconi, 1994). Public institutes in the three countries basically fund their research activities from government contributions and, to a small extent, from the sale of their resources (such as seeds, plants, animals and laboratory services), as well as from contributions made from national and international arrangements. The private sector receives little support from government revenues. Most of the growers' associations have imposed an obligatory or voluntary cess on exports and local commodities and processed products. For example, the Colombian coffee research centre is funded through profits generated from export sales made by the Coffee Federation, as well as an obligatory levy on all coffee exports, including those of non-members. An obligatory levy system, in practice, does not guarantee full collection. However, considering the high degree of dispersion of growers, and that potential research results are intrinsically non-appropriable, a voluntary levy system would definitely not be the best mechanism for supporting research funding (Cano, 1992). Similarly, most commodity boards have imposed a levy (obligatory or voluntary) on the value of exports or local marketing. However, for some commodity boards, the contribution to their budget is minimal, while their marketing activities and services are the main funding component of their research activities.

The Jamaican and Ecuadorian foundations (JAP and FUNDAGRO), which were designed to have a catalytic role in their technological agricultural system, are largely supported by grants from 'public' money, especially USAID. In contrast, the commercial private organizations such as Cargill, Hoechst and Alcan finance their research through the sale of their products and parent company budgets. Interestingly, private commercial organizations have had a higher annual growth rate in terms of research expenditures than that for growers' associations and commodity boards. The private commercial organizations have been taking an increasing role in agricultural research in the past ten years.

With respect to the structure of research expenditures, private-sector managers within the three countries revealed that, on average, around 45 per cent of their budget goes towards salaries, 35 per cent to operating costs and 20 per cent to capital costs. This contrasts markedly with the proportions allocated by the main public institutes where, on average, salaries account for 70 per cent of their budget. It is relevant to note that private commercial organizations allocate a higher portion of their research expenditures to operating costs and less to salaries than do growers' associations and commodity boards.

The nature of research

As argued in the conceptual framework, the respective roles of the public and private sectors within agricultural research can be established in relation to type of research (upstream or downstream), appropriability of benefits according to the nature of technology (appropriable or non-appropriable) and market size for research output or technology (large or small). In our interviews, considerable attention was given to interpreting the terms 'basic' and 'strategic' for the respondents who were given examples of each type of research. They had no difficulty in situating their research on the basic – adaptive continuum. From our survey, it was observed that the private sector does favour downstream research (applied and adaptive); while the public sector conducts mainly downstream research as well, it engages in upstream research (basic and strategic) to a greater extent than the private sector. This is shown in Table 2.[2]

Private-sector managers in Colombia revealed that 90 per cent of their research is applied and adaptive, while the public sector assigns 25 per cent of its resources to basic and strategic research, leaving 75 per cent for applied and adaptive research. This is consistent with our hypotheses that the private sector is inclined to conduct downstream research because this is less risky, less expensive and closer to the market than upstream research. For its part, the public sector is often obliged to carry out downstream research in staple goods and commodities with low export potential, where there is little private-sector interest.

It was hypothesized that the private sector would focus more on technologies that were mechanical and chemical in nature. Its biological work would favour hybrids more than improved varieties and agronomic technologies. In this first group of technologies, benefits are embodied in the product, making research benefits more appropriable by the private sector. It is not surprising that private non-commercial organizations such as non-governmental organizations and foundations, whose research outputs are freely accessible, generate or support the development of technologies yielding benefits that are more difficult to appropriate. However, some private commercial organizations are also working on non-appropriable (usually agronomic) technologies, especially when they have a significant share of the final product or technology market, or where the results can be confined within their respective organizations. Private-sector managers consider that, on average, about 38 per cent of their efforts are assigned to developing agronomic technologies. As expected,

TABLE 2 *Public- and private-sector roles in agricultural research, percentages*

	Colombia		Ecuador		Jamaica	
	Public sector	Private sector	Public sector	Private sector	Public sector	Private sector
Type of research						
Basic	10	5	2	0	5	0
Strategic	15	5	0	0	0	0
Applied	50	50	38	20	40	40
Adaptive	25	40	60	80	45	60
Nature of technology						
Agronomic	45	35	39	40	50	38
Biological	50	47	60	45	45	40
Chemical	0	8	0	9	3	5
Mechanical	2	6	0	3	0	10
Post-harvest	3	4	1	3	2	5
Food processing	0	0	0	0	0	2

Source: Falconi (1993, 1994).

private commercial organizations concentrate on developing technologies with more appropriable benefits. These include hybrid seeds, composite varieties (such as the Colombian variety of coffee, which is a mixture of 45 progenes), embryo transfer, artificial insemination, distribution of pharmaceutical products and biotechnology techniques. Nearly 45 per cent, on average, of the private sector's resources are assigned to developing biological technologies. The remaining 17 per cent of resources are channelled towards developing technologies that have appropriable benefits, such as agrochemical products, design of agricultural machinery, and post-harvest and food processing technologies. In contrast, the public sector concentrates most of its efforts on generating technologies with non-appropriable benefits. These include agronomic (for example, cultural practices and husbandry, production systems) and biological technologies (for example, genetic improvements on varieties, animal breeding, integrated pest management). The public sector is also involved in developing hybrid seeds, which has the effect of regulating the price of hybrid seed sold by private commercial organizations.

The private sector, in all three countries, tended to concentrate more on export commodities (traditional and non-traditional) than on staple products, while the public sector focused its efforts more on domestic staples and few traditional export commodities. Such a division of labour is expected because the potential benefits that the private sector would generate from staple products are marginal, while the public sector is expected to support the growers of such products.

Factors determining private-sector agricultural research behaviour

The conditions under which the non-public sector can be expected to contribute vigorously to technology development have been discussed in the economic literature (Pray and Echeverría, 1991; Griliches, 1984; Griliches *et al.*, 1987). They relate to the nature of the policy environment, the institutional make-up of the system and the appropriability of benefits from research. The degree of appropriability of the benefits from agricultural research is enhanced by favourable laws relating to plant breeders' rights and patents, barriers to competition resulting from the structure of the industry, embodied technology and time involved in developing new technology. A favourable policy environment depends on macroeconomic stability, a favourable (but not lax) regulatory environment and liberal conditions for writing off investments and repatriating earnings.

From our survey, it was possible to observe those factors or conditions that have had significant impact on private-sector involvement in agricultural research. In general, the observed determinants were consistent with those upheld in economic literature. However, a number of dynamic factors seemed to condition the private sector's entry into research. These are summarized below.

(1) *Liberalization of the economy.* Since 1990, the three countries have begun moving away from being an inward-oriented economy and have increasingly adopted outward-oriented economic policies. The macropolicy framework places major emphasis on policies and measures aimed at promoting macroeconomic stability, strengthening external competitiveness through export-oriented strategies, intensifying deregulation and liberalization of the economy, reduction of the size of the public sector and stimulating private-sector activities, improving balance of payments and ameliorating external debt. With respect to the agricultural sector, the main policies are elimination of import restrictions on agricultural products, abolition of food subsidy programmes, reduction of the interest rate, deregulation of marketing operations and divestment of public-owned agricultural lands and agroenterprises. It is expected that the implementation of these policies will benefit economic growth, and agriculture in particular.

(2) *Nature of technology.* The private sector does invest more readily in the generation of embodied technology (hybrid seed, machinery, and agrochemical products).

(3) *Availability of technology.* Private organizations, in all three countries, became involved in research activities mainly because they needed technologies for solving a visible problem (such as disease or reduction of yields) or for remaining competitive in the local or international market. Technologies were unavailable in the country or the research results provided by existing organizations did not satisfy quality standards. Consequently, some private organizations have created their own niches for certain research products. Biological and natural crises have also motivated private-sector agricultural research investment. For example, the

proliferation of pests in corn and of disease in cocoa induced Ecuadorian and Jamaican private organizations to undertake research; epidemic disease affecting cattle reproduction spurred the principal livestock association in Ecuador to become involved in animal research; and the 1983 flood which damaged the corn supplies of the De Kalb representative in Ecuador and subsequently affected its supplies of chicken and eggs induced De Kalb to conduct research in order to prevent future disasters.

(4) *Environmental concerns.* We argued in our conceptual framework that public action is needed to orient environmental research in socially optimal directions. A few private commercial organizations are carrying out environmental research because of legal requirements or competitiveness. For example, Alcan (Jamaica) must conform to legal requirements and be involved in soil research to restore mined-out bauxite lands. The efforts of some Colombian private organizations to reduce the consumption of fertilizers and chemicals by biological control is motivated by cost savings as well as environmental concerns. The Colombian coffee research centre is developing a mechanical method that significantly reduces water consumption and contamination in the processing of coffee beans. In addition to being ecologically friendly, it reduces costs and improves competitiveness.

(5) *Property rights.* In our survey, some private-sector managers expressed the need to establish an agricultural patent system. There is an extensive body of literature that argues that patents are an important stimulus for research development because they allow firms to exclude others from using an innovation. Unfortunately, there is little empirical evidence to gauge the impact of patents on agricultural research. In the three country cases, it was shown that the patent system protects agricultural input of a mechanical and chemical nature. But plant varieties and animal species are excluded from protection. However, in 1992, the Andean Pact countries, which include Colombia and Ecuador, took the decision to introduce plant breeders' rights (PBR) and agreed to a common model of PBR. On this basis, Colombia prepared a PBR law in 1993 which is currently in the process of being approved by the congress.

INSTITUTIONAL CHANGES

Given the growing importance of sustainability issues, the need for a more inclusive definition of the NARS to embrace universities, the NGOs and the private sector, and the special issues of intellectual property rights associated with new technologies it is becoming increasingly necessary to have some coordination of science and technology policy.

Science and technology policy

New changes brought about by the science and technology policy, macroeconomic policy and institutional changes are generating a favourable environment

not only for private-sector research investment but also for closer linkages between both public and private sectors in the three country studies. Over the past four years, both Colombia and Jamaica have made efforts to coordinate and guide the science and technology policy of private agricultural research. In 1990, the Jamaican government prepared a science and technology policy to provide a blueprint for the medium- and long-term development of the national science and technology sub-system. The government is planning to implement a national commission composed of public, private and university representatives under the aegis of the prime minister. It will be divided into sub-commissions whose task will be to oversee research activities in such areas as agriculture, industry, biotechnology and marine development while ensuring the coordination, monitoring, evaluation, promotion and allocation of funds for science and technology. It is hoped that this kind of institutional mechanism will help promote private-sector participation in the formulation, coordination and evaluation of research policy at the national level.

Policy for science and technology within Colombia has evolved significantly since its first national plan of integration in 1978. This reflects new challenges faced by the country, particularly those of competing in a more open economic environment. In 1990, the government established a new National Council of Science and Technology composed of 11 programmes or areas of work. One of the programmes, the agricultural science and technology programme, is jointly represented by the public and the private sectors. Their task is to coordinate sector science and technology planning, approve policy for agricultural research, promote funding for programmes in this field and integrate scientific advisory committees. At the same time, the Colombian government has supported the association of public institutions with private organizations to create corporations and foundations and to conduct special research and technology projects or programmes.

This new legal framework has provided the basis for privatizing the main actor in public agricultural research (ICA) in order to simplify its multiple functions, decentralize its decision processes and make its operations more efficient and competitive. In line with these objectives, ICA separated its responsibilities into two organizations in 1993. The first 'ICA Official', is in charge of phytosanitary protection, input regulation and coordination of ICA's research policy. The other, 'ICA-Corporation', has responsibility for promoting, strengthening and developing research and technology transfer. ICA-Corporation is a mixed entity, regulated under private law. This allows it greater flexibility in its organization, structure, planning and management, and better opportunities for association with the private sector, where the initiative has generated positive response.

Mixed organizational models: 'Fundaciones'

In the introduction, we indicated that one of our purposes was to shed light on the issues of who executes research, who funds it and who appropriates the benefits. There are no technologies that are purely public or purely private. Even where the technology is a public good there is no requirement that the

public sector execute the research. The public sector may even fund the development of technology of a private good nature if this is the incentive required to generate technologies that serve certain (for example, resource-poor) target groups. The 'Fundaciones' are an interesting attempt to deal with these issues. They receive public (aid) funds; they are governed by mixed boards; they commission research executed largely (but not exclusively) by the public-sector institutes and are supposed to make research more 'demand-driven'. The complexity of their accountability relationships is beginning to appear as a problem and their sustainability beyond aid funding is questioned.

The Ecuadorian foundation (FUNDAGRO) and the Jamaica Agricultural Research Programme (JARP) of the Jamaican Agricultural Development Foundation (JADF) are examples of the important linkages between the public and private sectors in their respective agricultural technology systems. Both FUNDAGRO and JARP, created in 1987, are private non-commercial and apolitical entities funded largely by USAID. Their mandates are to play a catalytic and coordinating role in revitalizing agricultural research, extension and education systems in these organizations' respective host countries. Therefore they stimulate their country systems to higher levels of integration, cooperation and productivity in technology generation and transfer.

The two foundations do not conduct research themselves but, through grants and contracts, support research undertaken by public and private organizations. Most of their research expenditures are oriented to financing downstream research (60 per cent of it 'applied' and 40 per cent 'adaptive'), especially research conducted by public institutes (for example, FUNDAGRO dedicated about 90 per cent of its research budget to INIAP), and the technology generated under their sponsorship is freely accessible on the market. A significant percentage of their budgets (for example, nearly 40 per cent of JARP's) is allocated to work on high-value non-traditional export crops (such as ornamentals/floriculture and tropical fruits) that is conducted by the public sector. The foundations also play a key role as research advisors and sponsor funds for new research areas of relatively high risk of failure, such as non-traditional export commodities, in order to provoke private-sector involvement.

In contrast to JARP, the Ecuadorian Foundation also conducts and supports technological transfer, aiming to fill gaps left by the public-sector extension service. About 40 per cent of its total budget is devoted to extension activities through its commodity programmes serving a clientele of medium to small growers. The foundation mainly transfers technology generated and validated by the public institute, INIAP.

Linkages

Since there are various degrees of 'publicness' and 'privateness' in all research, it is useful to study the mechanisms by which they interact. In the three countries cooperation is established through formal and informal channels. Most formal links are forged through research contracts where private organizations fund specific projects executed by public organizations such as ICA, INIAP, the Research and Development Division of the Ministry of Agriculture

(MINAG), universities and regional research centres. Seed and chemical certifications are a second example of formal linkages between the two sectors, though in this case regulatory linkages are obligatory. Informal links take the form of personal communications and participation of public researchers in private-sector activities such as demonstration plots, trial evaluations and approval of cattle-breeding societies. It is interesting to note that, in the three countries studied, the linkages of both sectors are most informal than formal and the contribution of contracts to their institutional budget has remained low.

From our survey, it was possible to gauge the degree of interaction between public and private sectors, as viewed by private-sector managers. Of the 37 private organizations interviewed, 15 stated that they had 'limited' research links with the main sponsors of public agricultural research (ICA–Colombia, INIAP – Ecuador and the Research and Development Division (MINAG) – Jamaica). Several reasons for these limited linkages were given. Public agricultural research institutes do not conduct research on commodities that are of most interest to the private sector. In certain research areas, the public sector is not very advanced, nor does it have the necessary resources (especially human capital) to deliver research results demanded by the private sector. However, most private organizations which reported limited research links with public institutes are financing, at least in part, specific research projects carried out by local universities. According to private-sector managers, dealing with local universities is much easier because there is less bureaucracy, closer relations with project leaders and more timely delivery of good quality research results.

On the other hand, there were about 17 private organizations that have extensive interaction with public agricultural research institutes. The causes of their success are implicit in the examples given.

(1) *Clear division of labour based on comparative advantage.* The Colombian Rice Growers' Association (FEDEARROZ) and Alcan-Jamaica have established a complementary relation with public institutes (ICA, MINAG). This has been possible because both sectors have set a good division of labour, each understands the comparative advantage of the other, clear objectives were outlined in the arrangement, and the product under research has an importance to the country's diet. For example, in the context of Colombian rice research, ICA and CIAT are responsible for upstream research while FEDEARROZ is responsible for evaluating and marketing agronomic recommendations. Another example is the analysis of Jamaican cattle performance on new grass varieties: MINAG is responsible for the screening and selection of varieties, while Alcan conducts the trials and evaluates the cattle performance.

(2) *Ensured funding brings partners together.* The factors that contributed to successful linkages in Colombian rice research are that rice fell under the mandate of an international centre (CIAT) located in the country; the local research institute (ICA) maintained a well established and complementary rice-breeding programme, and the rice growers' association had a secure flow of financial resources through an obligatory cess.

(3) *Shared facilities.* Some Jamaican commodity boards and Colombian growers associations have also formed collaborative links with their respec-

tive public institutes. Most of these private organizations cannot afford to build or maintain research facilities, since these are too costly. Instead, they set up relations with public institutes to utilize their experience, physical facilities and qualified researchers. For example, most of the Jamaican commodity boards use MINAG's facilities – research stations and laboratories – to conduct their trials and breeding experiments. Private researchers working at public-sector research stations are therefore provided with the opportunity to exchange information and make personal contacts. As a result, relations between the two sectors are enhanced, leading to opportunities for developing formal research projects.

(4) *Efficient regulation benefits both parties.* Colombian and Ecuadorian private seed companies have an obligatory relationship with public institutes because, by law, all introduced seeds must first be evaluated by public institutes before being marketed. In general, the interaction between the public institutes and private seed companies is good and seen as necessary in order to guarantee a quality seed market. Agrochemical companies have also set up good links with the public sector; as with the seed system, all imported or formulated agrochemical products must first be evaluated by public institutes if they are to be marketed. ICA has implemented a flexible, fast and decentralized certification process for agrochemical products since 1986. Agrochemical private companies execute their own agronomic tests (dosage, application) and ICA 'conducts' efficiency tests and issues certification. This process speeds up the evaluation of the agrochemical product and generates complementarity between the two sectors.

CONCLUDING COMMENTS

The private sector's importance in executing and funding agricultural research in the three country cases has increased significantly during the last 20 years. This is being driven, not only by the crisis of the national institute model, but also by the nature of technology that is being demanded. The Colombian private sector has shown a stronger performance than in the other two countries. It is better organized at the institutional level through its growers' associations; it takes an active role in the country's research agenda; and it has lower transactions costs and a comparative advantage over the public sector in certain research activities and especially in export commodities. Institutional changes involve creating bodies to give strategic direction to science and technology policy and mechanisms promoted by governments to 'privatize' part of the public research institute (for example, ICA, Colombia). A frequent approach is the creation of a national council, with public and private representatives, for the formulation, with private-sector involvement, of a science and technology policy. The expected approval of legislation dealing with plant breeders' rights has created positive expectations for enhanced private-sector involvement in executing and/or funding research activities.

There is more scope for increasing the role of the private sector in the three country cases. Although the public and private sectors have interacted through

formal (contract research) and informal channels, they have not realized the benefits of true synergy, except in a few specific cases (rice research in Colombia, cattle in Jamaica). Efforts to do this must start with a new strategy by public organizations to be more demand-driven and more responsive to clients. This may imply institutional changes in the technology system, such as those in Colombia, although the experience is still too recent to judge. However, there are also innovative mechanisms that do not require new institutions. The introduction or promotion of formal linkage mechanisms (competitive bidding schemes, joint ventures, collaborative research, cess system, contract research) and informal linkage mechanisms (professional meetings, information exchange) can contribute to enhance the relationship between the two sectors on potential areas of cooperation and the efficiency of their research outputs.

In the final analysis, the success of an enhanced public to private sector interaction will depend, not only on a favourable policy environment and the above recommended linkage mechanisms, but also on the understanding of the comparative advantages of each sector, the government's recognition of the role of technology as well as of agriculture in the development of the country, and the process of confidence building between the two sectors within their respective arrangements.

NOTES

[1]The research classification used in this report is based on that of the Consultative Group on International Agricultural Research (CGIAR, 1981). *Basic research* generates new scientific knowledge but has no direct commercial application. This is largely a publicly funded and executed activity. *Strategic research* addresses issues that normally influence the efficiency with which other research further downstream can be carried out. It is conducted by both public and private sectors, with the latter devoting its strategic research to particular themes that are applicable to the product or service it sells (for example, chemical companies that purchase seed companies and use biotechnology techniques to influence herbicide resistance to their varieties). *Applied research* creates technology with commercial applications. *Adaptive research* adjusts technology to specific needs of a particular set of environmental conditions. There are other research classifications such as the Frascati Manual (OECD, 1981) that categorize research by basic and applied and experimental development, as well as Evenson (1983) who uses pretechnology, prototype technology and usable technology. In all these classification systems, research should not be interpreted in independent stages but as a part of a continuum from more basic to more adaptive activities.

[2]Private-sector applied and adaptive research includes genetic improvements, reproduction in vitro, biological control, control of pests and diseases, animal food formulations, adjustment and evaluation of genetic material, cultural practices, validation of chemical drugs and post-harvest machinery. Public-sector basic and strategic research includes the characterizations of genotypes by molecular markers, seed inoculants to fix nitrogen, applications of new tissue culture techniques and the biochemical and physiological analysis of plant attributes. Out of the 37 private organizations surveyed, only three were involved in upstream research that focused on applications of advanced biotechnology techniques.

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