THE CHANGING DYNAMICS OF GLOBAL AGRICULTURE

A Seminar/Workshop on Research Policy Implications for National Agricultural Research Systems

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Private-Sector Participation in Agricultural Research and Development: Notes on Issues and Concerns[1]

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Introduction[2]

Scientific discovery and the resulting innovative technological processes are probably the most important elements in 20th century civilization. In agriculture, new cultivars and capital inputs have not only augmented yields and production, but also dramatically transformed agricultural societies and the well-being of individual groups. On the other hand, the pervasive, profound, and quite frequently asymmetric impact of technical change on the economic and social organization of society has increased the preoccupation with the development of mechanisms to control the direction and intensity of technical change.

In Latin America, and probably elsewhere in the less-developed world, discussion has mainly revolved around the creation of national research institutions that could guarantee adequate state participation in the production of agricultural technology. However, the economic and institutional developments in these countries during the past two decades have spawned private and semi-public organizations that are active in specific aspects of technology generation and transfer.

In market economies, the development of nonpublic research institutions is an integral part of the agricultural modernization process. This development is determined primarily by the formation of necessary preconditions related to the demand for technological inputs, production organization, the appearance and organization of social sectors with economic interests in technical change, and the growth of technological potential. In the last decade, these elements have been reinforced by the emergence of biotechnology, which changed not only the scientific base of agricultural research and development, but also the nature of the resulting technologies and the institutional context of the technological process in agriculture.

This scenario has profound implications for both the policy and organizational dimensions of national agricultural research and development systems, and the capacity of developing countries to fully exploit the potential of science and technology for agricultural development and economic growth. Here, we review some of the main forces behind the growth of the private sector in agricultural research and technology development, then discuss the new institutional situation, primarily in Latin American. However, since the basic forces behind this process are phenomena of a generic nature (for example, the role of technological development in market economies), the discussion could also be relevant to other regions of the developing world.

Agricultural Modernization and Institutional Change

The nature of the technology has important implications for the relative role of the public and private sectors in technology development. In the early stages of development, the quasi-monopolistic role played by public research institutions is practical – only the state could absorb the costs of research. These initial costs are

- relatively high because there is a shortage of trained personnel and an adequate research infrastructure is missing;

- risky because basic knowledge is lacking and markets are inadequate, etc.;

- difficult to recover.

Under these conditions, agricultural technology can be seen as a pure public good, and the institutional model that emerged assured the supply of technology and socialized research costs. The problem was viewed as one of transferring technologies from developed to developing countries, which required an infrastructure capable of adapting available technologies to local conditions. This formed the conceptual basis for international assistance that supported the development of public research institutions, usually following the US land-grant model.[3]

As agricultural modernization progressed over the last three decades, a number of changes set the basis for increased interest and participation by the private sector in agricultural research and technology development.

The public-sector role in the development of research infrastructure and human resources

The initial efforts of national agricultural research systems (NARS) in Latin America, as well as in other parts of the world, were oriented toward human and natural resources as well as other information considered essential for applied and adaptive research. Work in both of these areas was undertaken with extensive funding and technical support from the international donor community (Trigo, 1986). The result was a dramatic increase in the availability of adequately trained personnel and a widening of the information base for applied research activities.[4] Both aspects affected the costs of research and development (R & D) activities for the private sector. Private firms interested in developing R & D units preferred to hire researchers away from the public sector. This process was facilitated by the salary restrictions in public research institutions and universities.[5] At the same time the increased basic agricultural knowledge also lowered the risks associated with R & D, and even made possible work in other areas such as agrochemical evaluations and fertilization.

Producer and nongovernmental organizations in technology generation and transfer

Technology has become more important in the production decision-making process in both the public and private spheres. In general, as the availability of previously unused land diminishes, technological change becomes the only means of increasing production. Moreover, the increased use of non-neutral technological inputs, in terms of their effects on income distribution, has affected the direction and intensity of technological change.

Cooperative agricultural producer organizations and, more recently, nongovernmental research foundations, have become important actors in the agricultural R & D process. Producer organizations are important in cases where production is homogeneous and where the technological potential already exists.

The rice and sugarcane growers' associations in Colombia are good examples of how producer groups increasingly participate in technology development. In the case of rice, research and transfer activities began in the 1950s at the Colombian Agricultural Institute (ICA), but initiatives and responsibilities were gradually transferred to FEDEARROZ as this organization consolidated and developed its technical capacities. After CIAT (Centro Internacional de Agricultura Tropical) initiated its rice activities in the early 1970s, creating substantial "technological potential", the direct participation of FEDEARROZ became of real importance in a triangular partnership with CIAT and ICA. The case of sugarcane is somewhat different, because the sugarcane trade association (formed mainly by the sugar-mill owners) created an independent research center with ties to the public system through the participation of government representatives on its board. This center (CENICANA) is now formally mandated to undertake all sugarcane research in the country (Samper, 1982).

The influence of farmer organizations extends well beyond cases of direct participation in research activities. As their institutional and technical capabilities consolidate, they have also played an increasing role in setting the research agendas of public institutions (dairy products, soybeans, maize, and palm oil in Ecuador) and in funding research activities (National Maize Committee and National Cotton Fund in Peru, wheat and cocoa in Colombia, industrial tomatoes in the Dominican Republic and Panama, and the multicommodity case of the Patronato de Sonora in Mexico) (Barsky, 1985; ISNAR, 1983; Paz and Planas, 1985).

Producer organization involvement in the adaptation and dissemination of technology has also become significant. In some cases, producers have virtually assumed the role of the public extension system through the development of their own technical assistance mechanisms. Following the model developed by the French Consortia for Agricultural Technology Experimentation (CETA), the CREA groups in Argentina exemplify this trend. First created in the late 1950s, the CREA model spread quickly during the following decade, and became especially strong in the 1970s. In the early 1980s in Argentina, there were about 150 local groups with more than 1500 individual members. The model has spread to other Southern Cone countries, notably Chile and Uruguay, and there are indications of similar initiatives in a number of other countries of the region (Martinez Nogueira, 1985).

Another important institutional development is the research foundation. Within this group, it is necessary to distinguish between those mandated to perform research themselves and those that fund research undertaken by other public and/or private research organizations.[6] FUSAGRI and FUNDESOL in Venezuela, the Fundación Hondurea de Investigación Agropecuaria – FHIA in Honduras – and Fundación Chile are cases of the first type. Even though each responds to a particular situation, all were created to mobilize technological knowledge with a problem-solving orientation, and a highly flexible, nonbureaucratic administrative structure. Although applied research is the core activity, they have very strong transfer programs, and organizations such as Fundación Chile go as far as the design and implementation of agroindustrial projects to exploit specific production potentials or market opportunities. Research funding foundations are more recent, and are still in the development stage. The Fundación Dominicana de Investigación Agropecuaria in the Dominican Republic and FUNDAGRO in Ecuador belong to this group. In most cases, these foundations develop as external donors seek to provide alternative sources of funding, but they still must consolidate operations and prove their long-term financial viability. Most depend on external donor grants (primarily USAID).

Regardless of whether they perform R & D activities themselves or are restricted to funding research, the foundations are important because they add to a country's research capability, as well as widening the research support base. Potentially, they can fill two critical niches in the process of technology generation and transfer.

The first is the need to link technology generation with technology utilization, something that public institutions have not done efficiently. This is particularly important for agroindustrial crops, but is also proving critical for food crops, as some of the FUSAGRI experiences in regional development show.[7] Second, they provide an institutional "bank" for private-sector resources to support research. Improved technology is increasingly recognized as a critical input for agricultural development, but in most cases the domestic private sector lacks the economic size to directly undertake needed R & D activities. Because of their bureaucratic image and bad track record, public-sector organizations are not an attractive alternative as direct recipients of private-sector funding. In this context, research foundations could provide an ideal base for project development and monitoring, with the research itself conducted by either the public-sector centers, universities, or other research institutions.

Development of markets for technological inputs

Agricultural modernization implies a substantial modification of market incentives for private participation in technology generation and transfer. The most important modification is the opening and widening of previously nonexistent or very limited markets for technological inputs. Several factors are interrelated. First, there is the tendency for seeds, agrochemicals, and machinery to become more important in relation to agronomic practices as sources of productivity growth. Then there is the rapid growth of commercial agriculture as compared to the traditional sector, probably as a consequence of its better access to credit and technical assistance. Together with the growth of the commercial sector, modernization also develops the communication and service infrastructure necessary for getting new inputs to the farm, thus expanding the markets for these inputs even further.

The incentives for private participation in R & D activities are market growth and lower input distribution costs (lower level of investments and shorter payback period). This is further reinforced by property protection, which the passage of plant breeders' rights legislation in a number of countries has extended to seeds, while agrochemicals, machinery, and veterinary products are protected by the patenting laws regulating the industrial and pharmaceutical sectors. Under these circumstances there has been rapid growth in these industries.[8]

This is neither new nor unique to Latin America. The experience of the United State indicates a similar trend in the change from what was initially a primarily public system, implemented through the creation of the land-grant colleges and the US Department of Agriculture experiment stations, to the present situation, where about half of all agricultural research is funded by private firms.

In Latin America, and probably in other less-developed regions, this process has gone beyond what regional and national conditions warrant. This is largely due to the increased importance of multinational firms. Their multinational character has relaxed some market constraints because technological knowledge and innovations developed in one country can be used in another. The integration of national firms into multinationals also implies differential access to technological potential – the larger scale of operations permits their direct participation in the generation of new basic knowledge (Trigo and Pineiro, 1981).

Another important form of private R & D and technology transfer is through the activities of agroindustrial complexes, usually working in industrial crops and high-value aggregate products. In many cases, these firms develop their own R & D units and technical assistance systems to assure a continued supply of raw materials that meet their specifications (de Janvry et al., 1987). Examples include the following:

- the dairy industry in Argentina, where the large co-ops (SANCOR) and some private firms like La Serenisina have taken over almost all R & D functions, including technical assistance to farmers;

- in Venezuela, PROTINAL (an animal feed concern) has taken over variety development for sorghum, and the POLAR group (maize milling) has created its own experiment station to develop soybeans and maize varieties. In both cases, the initial R & D efforts led to the creation of seed companies to market the products that were first developed for in-house raw material needs.

Vegetables and strawberries in Mexico are also important. However, in this situation, R & D was provided by the transnational corporations that exported fresh or frozen produce to the US market.

A number of more recent initiatives in pineapples and other fruits in Central America developed as part of the Caribbean Basin Initiative, an export promotion program of the US government to facilitate exports from that region to US markets. This form of participation can be expected to increase substantially as the proportion of agricultural production subject to processing before reaching its final market becomes higher, and as efforts to diversify agricultural exports and increase their value-added content are intensified.

Biotechnology and the Privatization of Agricultural R & D Activities

Biotechnology is significantly changing the scientific and institutional basis of agricultural technology generation and transfer.[9] Several aspects are important for developing countries. The first is that biotechnology is radically different from previous technologies because, for the first time, commercially relevant technical information is at or close to the frontiers of basic research in molecular and cell biology.

This is changing the traditional dichotomy between basic and applied research and altering linkages in the flow of scientific information. Work is now being done in biotechnology by universities and research centers with no previous experience in agriculture.[10] Such a shift poses a significant problem for national research institutions in Latin America and the Caribbean, which have no links with these new centers of valuable technological information. A related problem is that biotechnology requires scientific talents different from those available at the traditional agricultural institutions. Eventually, the greatest obstacle preventing developing-country research institutions from participating in biotechnology may be that few of their staff are trained in molecular and cell biology, virology, and immunology (de Janvry et al., 1987; IICA, 1987).

A second important facet of biotechnology is its relationship with the private sector (de Janvry et al., 1987). During the Green Revolution, most essential components were handled through public (international or national) institutions, whereas biotechnology in the private sector, prompted by the proprietary nature of resulting technologies, is already an important force and will probably increase. Even though universities are playing an important role, the development of biotechnology in industrialized countries is characterized by market incentives and massive private investment, both from multinational corporations and from venture capitalists supporting small biotechnology firms. Private-sector involvement today is underscored by about 300 firms actively working in the field in the United States, 150 in Japan, and about 100 in other countries. Monsanto and Dupont, two of the large corporations most active in this area, have invested $150 million and $80 million, respectively, in building state-of-the-art biotechnology laboratories (Riggs, 1985; Lohr et al., 1986), and many other corporations are involved in many different sectors of the biotechnology industry (Table 1).

It is not easy to assess the possible impact of biotechnology on Third World agriculture. Table 2 highlights an additional characteristic of biotechnology that sets it apart from the traditional approach: it is not product specific. Technology has traditionally been product specific, which was a key factor in shaping the organization of agricultural research and technology. Biotechnology, on the other hand, is *process* based and cuts across products. This will strengthen private participation in agricultural R & D as numerous factors change the industrial organization of the agricultural input business, with greater participation by transnational corporations. This is important for the development of national strategies in this field (de Janvry et al., 1987; IICA, 1987).

Table 1. Numbers of US Companies in Specific Technologies and Markets

	Markets												
Technologies	AG	BL	BM	CM	DG	EN	FP	FU	MN	PS	PH	TW	VT
Cell culture	70	113	15	41	110	17	33	16	6	26	86	11	76
Cell fusion	48	104	8	32	111	8	23	9	3	19	67	7	60
Fermentation	60	81	28	53	63	22	42	19	6	27	73	18	46
Enzymology	44	71	16	41	60	14	34	10	4	22	55	12	40
Process control	17	23	5	19	20	4	9	3	0	9	24	3	14
Purification	46	94	16	51	87	14	31	9	1	18	73	10	52
Recombinant DNA	58	87	16	44	80	17	33	15	4	28	70	17	52
Gene synthesis	8	11	3	4	11	2	3	3	3	4	13	3	8
Large-scale purification	35	73	10	36	60	8	26	6	1	16	60	7	35
Separation	45	79	12	43	74	11	31	8	2	17	66	9	45
Sequencing	22	32	3	22	28	6	13	4	1	10	29	4	15
Synthesis	27	45	5	33	41	8	14	3	0	15	39	4	26
Total expenditure (US$)	110	181	34	88	178	31	66	27	8	42	140	25	106

SOURCE: Riggs (1985), as cited in de Janvry et al. (1987).
AG = agriculture; *BL* = biologicals; *BM* = biomass; *CM* = chemicals; *DG* = diagnostics; *EN* = energy; *FP* = food processing; *FU* = fuels; *MN* = minerals; *PS* = pesticides; *PH* = pharmaceuticals; *TW* = toxic waste processing; *VT* = veterinary.

Table 2. Markets and Biotechnologies Relevant to Food Systems

	Markets												
Technologies	AG	BL	BM	CM	DG	EN	FP	FU	MN	PS	PH	TW	VT
Bioprocessing		x	x	x		x	x	x	x	x	x	x	
Genetic engineering	x	x	x	x	x	x	x	x	x	x	x	x	x
Ecological engineering	x		x									x	

SOURCE: Riggs (1985), as cited in de Janvry et al. (1987).
AG = agriculture; *BL* = biologicals; *BM* = biomass; *CM* = chemicals; *DG* = diagnostics; *EN* = energy; *FP* = food processing; *FU* = fuels; *MN* = minerals; *PS* = pesticides; *PH* = pharmaceuticals; *TW* = toxic waste processing; *VT* = veterinary.

The Privatization of Research and Technology Development

The trend is for the private sector to be more involved in agricultural R & D activities. In addition to institutional and market-force changes associated with the modernization process, biotechnology and more exclusive patenting criteria have reinforced and broadened the trend. All these factors have definite policy and organizational consequences for the systems of national agricultural research and technology transfer. In the remainder of this section, we briefly discuss some of the issues emerging from this process. However, neither the list nor the treatment is exhaustive, as the process is still evolving: many of the possible consequences or elements discussed are still hypothetical, and we lack sufficient information for an in-depth analysis.

The privatization of knowledge

The increasing participation of the private sector in R & D activities and the emergence of biotechnology has important consequences for the organization of research and the free flow of scientific knowledge. As the development of commercially relevant technical information comes closer to basic research, the traditional dichotomy between basic and applied research is significantly altered, and with it the linkages for the flow of scientific information. Furthermore, the possibility of patenting research results means that an increasingly significant portion of scientific knowledge will be withdrawn from the public domain.[11]

These trends have important implications for technological institutions in developing countries. Such institutions once looked to the universities in developed countries (most notably, those of the US land-grant system) and to the international agricultural research centers for basic and strategic research results. They now find that the information they need is controlled by private companies or emerges from basic science laboratories which, all too often, have significant connections with private industry. The information is either protected by patents or subject to "industrial secret" practices because of its potential commercial value. The developing countries have no substantial ties with these companies nor easy access to them. This new "academic industrial complex" represents a significant change in the organizational structure of the systems of agricultural science and technology in the developing world (Kenney, 1986). Without easy and free access to basic, strategic scientific information, it is not clear how the NARS could continue to perform their functions. Moscardi (1988) points to two problems they must confront:

- relatively slow and increasingly costly access to new knowledge and specific technologies;

- the bias of new technologies in terms of input use and relevance for local conditions.

The latter is of special importance for tropical and subtropical areas.

Activities of transnational corporations and national technological development

The modernization process and the opening of developing country markets for technological inputs not only brought private-sector involvement into R & D, but also an increasing participation by multinational corporations in agriculture and agricultural supply industries. The growth of biotechnology has reinforced this tendency. New plant breeding technologies and changing patent legislation are leading to a restructuring of the industry, integrating previously independent segments (seeds, agrochemicals, etc.) into highly concentrated multinational conglomerates.

Until the 1970s, inputs for crop and animal production were generally marketed by separate firms for each product area: seeds, chemicals, pharmaceuticals, machinery, and petroleum products. However, these input industries have been restructured, and the research process has been realigned.

The first factor in the transnationalization of the original seed companies occurred as profitable markets opened in the developing world. This developed both through the creation of subsidiaries and the take-over of already existing developing-country seed firms. The second, and probably more important, factor was the acquisition of these firms by larger ones, mainly agrochemical, oil, grain trading, and pharmaceutical companies. According to de Janvry et al. (1987), this was the result of two separate but interrelated forces.

First was the decline in the profitability of the chemical industry when energy costs and environmental controls increased during the mid-1970s. This led many of the large chemical companies to diversify and enter specialty end-product markets (Kenny, 1986). Second was the passage in Europe of legislation to secure rights for plant breeders in the early 1960s, along with the Plant Variety Protection Act in the United States in 1970. The possibility of establishing proprietary protection on genetic materials and the natural complementarities between seeds and agrochemicals at the marketing stage made seeds an obvious and optimal road for diversification for these companies (Mooney, 1979). It now seems likely that virtually all seed companies will become centerpieces of transnational corporations (TNCs).[12]

In more recent times these companies, seeing the tremendous growth of the biotechnology industry, have begun to finance biotechnology research on a contractual basis from universities and smaller start-up firms, and to invest relatively large sums in in-house R & D units.

From a general perspective, the growing importance of TNCs in agricultural technology supply industries could be seen as positive. To the extent that they are truly international corporations with research facilities around the world, the privatization of applied research may actually benefit developing countries, particularly in export markets, by giving them rapid access to state-of-the-art technology at the same time and price as everyone else. This would remove part of the advantage that developed countries have in terms of early access to new technologies, but it would also raise a number of problems (de Janvry et al., 1987).

First is a possible bias in research priorities toward the development and promotion of technological packages which reflect a global corporate strategy to integrate seeds with a company's own chemicals, rather than breed for genetic resistance to abiotic stresses, insect pests, and diseases. This will increase the dependence of agriculture on purchased inputs, which will favor larger commercial agriculture over small holders.

Second, the expansion of the TNC seed business could further narrow the genetic base of important staple crops such as maize, wheat, and sorghum, which would increase the risks of widespread crop failure in many parts of the world.

Finally, there would be broader implications of economic and food security that would result from increased dependence on TNC marketing networks for strategic technological supplies. Capital-intensive technologies may be in opposition to the prevailing economy in developing countries where natural resources and/or labor are relatively abundant compared to capital resources. At the same time, many countries will create a high "political adjustment" factor to maintain national control of the strategic factors that affect food production and agricultural exports. Furthermore, TNCs concentrate their efforts on crops and technologies for which there are markets of significant size, so many crops and problems will not be included in their R & D strategies. All these elements highlight the importance of continued development of national R & D capabilities together with clear policy definitions concerning TNC participation in national markets for agricultural supplies.

The ever-increasing need for a comprehensive national agricultural science and technology policy

The transformations discussed in the previous sections have major implications for the design of technology policies for the agricultural sector. Agricultural modernization, with its concomitant industrialization processes, converts on-farm production into an ever-smaller component of the sector. Backward (input) and forward (processing/marketing) linkages assume greater importance. The specific nature of this process may differ between places and commodities, but the general trend is usually the same: as agriculture and industry grow increasingly interdependent, agricultural production should be viewed as one phase of the agroindustrial production chain, and it becomes necessary to consider the policies that govern agriculture and technology in the context of policies that govern industry and other sectors.

The tendency toward increased private-sector participation in agricultural R & D activities also implies the passage from a relatively centralized system to a highly diversified one. This raises the issue of how to integrate diverse efforts into a coherent whole, making optimal use of opportunities and available resources.

The new biotechnologies also affect the scope of policies that govern agricultural technology. As basic science grows closer to technological development, innovations in agricultural technology need to be viewed in the broader context of overall policies for science and technology in a country. Thus, policymakers must consider agricultural research centers along with the whole complex of scientific and educational institutions.

Policies for technology in the agricultural sector have traditionally amounted to little more than decisions on resource allocation for research within the national public research institutions, with little thought given to the broader context.

In the early stages of the system, the monopoly of national research institutes implied that the direction and nature of the technological process was indirectly determined by the processes of priority setting and resource allocation in these organizations. As the importance of their role diminishes and they become but one of the alternative sources for the supply of new technologies, the direction of technological change will depend more and more on market forces.

The potential contribution of technology to agricultural development and economic growth can be fully tapped only if full consideration is given to the interdependence of different sectors and the impact that macroeconomic policies have on technological behavior in the agricultural sector.

Further information is needed on the specific ways these interactions take place. In some cases, changes need to be introduced in the processes by which policy decisions are made, so that decisions on research priorities and resource allocations will be consistent with economic and agricultural policy. This will be possible if forward-looking economic planners and private-sector suppliers of modern inputs, as well as the different research clientele groups, are incorporated into the policy-making process.

The role of public-sector institutions

With the emergence of new private sources of technological knowledge, we are witnessing a progressive deterioration of public-sector research institutions. This situation could mainly be a consequence of the budgetary restrictions derived from the debt crisis in the developing world. But it is also the result of what is perceived as the ineffectiveness of public organizations to reach farmers, particularly the smaller ones, and meet their technological needs. Under these circumstances, and if the technological process is totally subject to the rules of market behavior, the deterioration of public research institutions will continue and probably worsen, as a vicious circle of lack of impact due to operational budget restrictions and reduced support sets in.

This scenario is of particular importance in the developing world because the agricultural sector is characterized by the coexistence of productive sectors at different stages of modernization. Within this structure, increasing participation in the supply of technological services by private and semi-public sources, together with the deterioration of public institutions, implies the potential widening of existing differences. Private sources will tend to service only those in the more advanced segments with technological demands oriented to the capital inputs they offer. This is important for small-producer and peasant economies in general. With the high heterogeneity of farm types and environments, they seldom represent profitable alternatives for the private sector. Moreover, the basic structural conditions necessary to facilitate producer organizations don't exist.

In this context, it is clear that there is a need to revise the role of the public sector in the technology development process, so that it can function effectively in the new institutional and economic situation and continue to perform its service function for the non-modern sector. In general terms it seems that an appropriate division of labor would focus public-sector institutions primarily on the generation and transfer of technologies for the small farm sector, and in those areas where either the size of the markets (small regions) or the nature of the technologies (agronomic techniques, resource management research) offer no possibility to recover R & D costs. On the contrary, the private sector should be encouraged to develop technologies where the proprietary nature permits cost recovery. This broad division of labor, however, does not imply that the public sector should not continue working on basic or strategic research to assure a minimum level of technological independence at the national level.[13]

The role of the international agricultural research centers

The privatization of knowledge will also affect the ability of the IARCs to maintain their relationships with national programs. As with the national research institutions, the problems will involve linkages to the sources of basic scientific knowledge. As the IARCs took shape, most funding came from the governments of developed countries and from philanthropic foundations. IARC scientists were at the forefront in establishing a free flow of scientific information among researchers, internationally, from diverse countries – north and south, socialist and capitalist. Because the private sector showed little interest, the limited resources of IARCs and LDC governments were used to establish input distribution networks and technology transfer systems. IARC scientists released new varieties into the public domain – freely available at a nominal cost to anyone interested. Virtually all technical information was available in the public domain from research institutes in developed countries, where the basic technical concepts had long been established.

The newly emerging biorevolution is altering the institutional structure of international agricultural research in many ways. Private companies now have sufficient technical information to engage in LDC-oriented plant-improvement research. Multinational chemical and seed companies, concerned that their technology be adequately protected by patents and other intellectual property restrictions, are unwilling to share their findings with public institutions. They know that the information might at some point prove to be profitable. Private firms are pushing to extend the Plant Variety Protection Act and patent and trade-secret protection in this field, thereby forcing the IARCs to consider new strategies in response to privatization of germplasm, research processes, breeding lines, and varieties. This tendency, although stronger in private firms, is starting to show up in universities, where there is already a formal discussion about the patent rights of scientists working with public funds.

It is still not entirely clear how these factors will affect the performance of the IARCs. It is evident that if these centers are to continue providing meaningful assistance to national programs, they must revise some of their basic policies. Their relations with the private sector need to be recast, and their involvement in basic or fundamental research must be rethought in response to greater restrictions on the free flow of scientific information (Buttel, 1986).

The funding of R & D activities

These institutional developments open a key source of new funding for agricultural R & D activities. Private resources will be important to help widen the support base and free up public resources. Furthermore, in the case of heavily indebted countries, attracting private resources for technology generation and transfer represents one way to mitigate the impact of the budgetary crisis on public research institutions. Establishing a link between the public and the private sector, however, is not easy.

Many countries still lack a tradition of interaction with private-sector research and development and need institutional mechanisms for such cooperation. As a result, the private sector often finds it difficult to finance research projects in public research institutions. In turn, public-sector scientists are often prevented from participating in private-sector research and development. The pace of change in this area is very slow, in part because of a long history of mutual suspicion, but also because private firms in the developing world have not traditionally been willing to spend on R & D. To a certain extent, this is because TNCs dominate and, in many research-intensive industries, do their research elsewhere. Local firms in most cases lack experience in translating research results into production activities (Waissbluth et al., 1985). The direct transfer of technology from abroad has also tended to discourage innovation in this area.

Important initiatives have already begun to develop public-private funding linkages. One example is the case of producer associations and research foundations in a number of countries, as described earlier. More complex mechanisms, however, are needed in response to the increasingly proprietary nature of agricultural technology. Argentina recently entered this area when INTA introduced a system of joint ventures with the private sector, allowing local firms to make full use of its R & D capacity, while at the same time strengthening its own budgetary situation and allowing scientists to benefit from at least part of the commercial value of their research findings (Moscardi, 1988). However, further innovations are still needed to modernize the prevailing bottom-up planning and make it more responsive to final users. This will preserve public-sector research while enhancing the flow of personnel and financial resources between the public and private sectors. International technical cooperation has an important role to play in this process by facilitating the analysis and exchange of experiences among countries, and providing assistance to specific development projects when needed.

The importance of increased cooperation between the public and private sectors goes well beyond the funding issue. It will have a great impact on a country's ability to exploit new scientific developments, particularly biotechnology, in the field of agricultural inputs and new market opportunities related to export diversification.

In many countries, especially the smaller ones, TNCs already control input industries, and local firms are merely distributors of TNC products. The transition to biotechnology may not bring great change. Even so, independent or state-run suppliers of seed, chemicals, and fertilizer will not be able to compete unless the R & D capacity already existing in the public sector can be used to sustain their competitiveness in local and regional markets (de Janvry et al., 1987; IICA, 1987).

Effective R & D support is also the key for new export markets. Many opportunities already exist, but they could be identified and made more accessible by government activity. Without greater coordination between the public and private sectors, however, these opportunities will be lost or undertaken as part of TNC R & D efforts, and developing countries will miss the opportunity to access critical private funds for research and to exploit national innovations.

Some Concluding Comments

Over the last quarter of a century, institutions in the developing world that generate and transfer technology have grown dramatically and have had a tremendous impact on agricultural improvement and economic growth. A number of specific cases – grains in Argentina, soybeans and wheat in Brazil, potatoes in Ecuador, rice in Colombia and the Dominican Republic, and wheat in Mexico – attest to this process. It is also clear that in Latin America and the Caribbean, those countries that invested more on research and development are the ones that show a better agricultural performance overall (Scobie, 1977; Moscardi, 1988).

Public agricultural research organizations have been at the center of a successful technological effort. At the same time they have been major contributors to the necessary conditions that will allow nonpublic organizations to become active participants in the technological process. Scientific developments, particularly biotechnology, have produced a new institutional situation where public institutions are no longer the sole suppliers of new technological knowledge, but rather, share the stage with a large, increasing number of alternatives, particularly private industry.

Parallel to these institutional developments, the debt crisis has limited the operational capacity of national research organizations and has impaired their ability to deliver what is expected from them.

All these elements make evident the need to review the prevailing institutional model and introduce changes and adjustments, so that it can continue to meet each society's demands for agricultural technology. These changes imply a redefinition of the scope of the policies that govern agricultural technology and the role that public-sector institutions should play. There will also be a need to develop specific mechanisms to cope with issues such as the interaction between the public and private sectors, and the effects of biotechnology on the workings of national systems. It is important to stress that, even though public research organizations may have lost the quasi monopoly they maintained earlier, they are still the centerpiece of national agricultural science and technology and will continue to play a key strategic role in the process of technological change. The issue is how to adapt the model to exploit the modernization process and the diverse new participants. The latest increased availability of international technical knowledge must be utilized while retaining the capacity to direct R & D toward national development priorities and maintain a reasonable degree of social control of the innovative process.

In this paper we have advanced our views on these issues as an initial contribution to on-going analysis and discussion. We have addressed the issues in a general way, but from a perspective strongly influenced by the Latin American situation. The discussion of policies and alternatives for specific situations will of course require proper consideration of the particular agroecological and socioeconomic characteristics of each country.

Notes

1. The author wishes to acknowledge the contributions of the staff of IICA's Technology Generation and Transfer Program, particularly Jorge Ardila, Eduardo Lindarte, and Walter Jaffe.

2. The ideas and issues presented in this paper were developed on the basis of some of the author's previous work (Trigo and Pineiro, 1981; Pineiro and Trigo, 1985; Trigo, 1986), as well as the work of others such as IICA (1987), de Janvry et al. (1987), and Moscardi (1988).

3. In the Latin American context, this process created a number of research institutions that today constitute one of the region's most important assets for agricultural development. They include the National Institute of Agricultural Technology (INTA) of Argentina, founded in 1957; the National Institute of Agricultural Research (INIAP) of Ecuador, founded in 1959; the CONIA/ FONAIAP complex in Venezuela, which began operations from 1959 to 1961; the

National Institute of Agricultural Research (INIA) in Mexico, circa 1960; the Agricultural Research and Outreach Service (SIPA) in Peru which, after successive modifications, became the National Institute of Agricultural Research and Outreach (INIAA) in 1984; the Colombian Agricultural Research Institute (ICA), founded in 1963; and the Agricultural Research Institute (INIA) of Chile, founded in 1964. The 1970s saw the establishment of the Empresa Brasileira de Pesquisas Agropecuarias (EMBRAPA) in Brazil, the Bolivian Institute of Agricultural Technology (IBTA), the Institute of Agricultural Science and Technology (ICTA) in Guatemala, and the Agricultural Research and Development Institute (IDIAP) of Panama. Efforts to create similar institutions are under way today in Uruguay and the Dominican Republic (Pineiro and Trigo, 1985).

4. Between 1960 and 1984 the human resource base for agricultural research in Latin America grew at an annual rate of about 6.5% per year, increasing from about 1000 researchers in 1950 to over 8500 in 1984. In specific countries the evolution followed approximately the same tendency as the region:

   - At EMBRAPA in Brazil, the total number of researchers between 1974 and 1985 grew from 872 to 1650 (an annual rate of almost 6%).

   - At ICA in Colombia, the number of researchers between 1962 and 1988 went from 137 to 603 (an annual rate of 5.9%).

   - At INTA in Argentina, the increase was from 640 researchers in 1958 to 1467 in 1978 (an annual rate of 4.2%).

   - At INIFAP in Mexico, the growth rate between 1977 and 1985 was 9.7%, when the number of researchers went from 929 to 1949.

   These figures are the author's estimates and are based on data from IICA and ISNAR publications.

5. For an extensive discussion of this process in Argentina, Peru, and Colombia, see Trigo et al. (1982).

6. For a more complete discussion of the case of the research foundations see Lindarte (1986).

7. For a detailed discussion of the case of FUSAGRI see Penango and Avalos (1986).

8. An idea of the quantitative importance of market incentives can be seen from the evolution of modern input consumption. For the whole of Latin America, the

proportion of the area sown to modern varieties grew from 11% to 83% for wheat and from 4% to 28% for rice between 1970 and 1983 (Scobie, 1987). The fertilizer consumption index between 1979 and 1985 grew at about 13% per year for nitrogen, 7% for phosphate, and 13% for potassium (FAO, 1986-1987). The net trade of pesticides increased fourfold between 1970 and 1975 (de Janvry et al., 1987).

9. The principal techniques identified as biotechnologies are cell/tissue culture, cell fusion/hybridoma production, recombinant DNA techniques, gene synthesis, separation, fermentation, enzymology, purification, large-scale purification, sequencing, and process-monitoring control (Riggs, 1985). Only cell fusion, recombinant DNA, and gene synthesis are considered genetic engineering; the rest can be termed *bioprocessing technologies*.

10. Hard evidence in this sense is difficult to find. However, a recent survey (Roca, 1986) provides some interesting insights: of the 206 institutions included in the sample, only 51 (24.6%) could be classified as agricultural. Of the 106 responding institutions, only 39 (36.8%) were agricultural.

11. This table provides an indication of the extent of TNC involvement in the seed industry, and by extension, the level of integration with crop inputs supplied by agroindustries:

Industry	Country	Estimated turnover (million US$)
Pioneer Hi-Bred*	USA	520
Royal Shell (oil)	UK, Netherlands	200-300
Sandoz (phamaceuticals)	Switzerland	290
LaFarge Coppee/ORSAN Semences	France	200
Volvo Provendor (automotive) (Hilleshop/Weibull)	Sweden	170
Pfizer/Dekalb* (pharmaceuticals/seeds)	USA	150
Upjohn/Asgro* (pharmaceuticals/seeds)	USA	140
Ciba Geigy/Funk (chemicals/seeds)	USA	130
Lubrisol/Agrigenetics (chemicals/biotechnology)	USA	110
Cargill (agribusiness)	USA	80-110
Elf Aquitaine/Sanofi (oil/seeds)	France	90
Rhone Poulenc (chemicals)	France	n.a.
Monsanto (chemicals)	USA	n.a.
Occidental Oil (oil)	USA	n.a.
ARCO Seeds (oil/seeds)	USA	n.a.
Continental Grain/Pacific Seeds (agribusiness/seeds)	USA	n.a.

SOURCE: Grooseman (1987).
*Traditional seed company.
n.a. = not available.

12. Basic research results, if not completely withdrawn from the public domain, will at least be delayed until there is a certainty that making them freely available does not diminish the possibilities for their commercial exploitation. The 1981 US Supreme Court decision Diamond vs. Chakrabarty made it possible to patent novel living organisms and opened the way to protect and commercially exploit basic knowledge. To date, not many countries have accepted the possibility of patenting living organisms or seeds (agrochemicals and fertilizers are already included in existing patent laws), but there is an on-going discussion about this topic in the International Union for the Protection of Industrial Property. The consequences of patent laws for seeds could be very far-reaching. Plant breeders' rights legislation does not prevent other breeders from using protected varieties for further breeding purposes. Patent protection by taxing use would even make breeders pay for the use of protected seeds in their research. The consequences of such a situation need not be elaborated (for a further discussion of this topic, see Kloppenburg 1985).

13. In the seed industry, which is increasingly dominated by TNCs, many countries will want to have crop improvement programs capable of supporting the local production of improved seeds to safeguard against oligopolistic behavior, excessive dependence on other countries, and a bias toward the development of improved varieties with undesirable traits, such as excessive dependence on the use of agrochemicals.

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