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TECHNOLOGY GENERATION AND TRANSFER PROGRAM

"PRIVATE SECTOR PARTICIPATION IN AGRICULTURAL RESEARCH AND DEVELOPMENT: NOTES ON ISSUES AND CONCERNS"

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PRIVATE SECTOR PARTICIPATION IN AGRICULTURAL RESEARCH AND DEVELOPMENT: NOTES ON ISSUES AND CONCERNS 1/

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I. INTRODUCTION

Scientific discovery and the resulting innovative process in technology are probably the most important elements in twentieth-century civilization. In agriculture, new varieties 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 brought about an increasing preoccupation with the development of mechanisms that will allow for adequate social control of the direction and intensity of technical change.

In Latin America, and probably elsewhere in the less-developed world, discussion on this subject has mainly revolved around the creation of national research institutions that could guarantee adequate state participation in the production of agricultural technology. However, it is becoming increasingly evident that the economic and institutional development in these countries during the past two decades has brought about the development of private and semi-public organizations that are active in specific aspects of technology generation and transfer.

In market economies, the development of non-public 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 brought about a substantive change not only in the scientific base of agricultural research and development, but also in 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 promoting 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 go on to discuss concerns and issues arising from the new institutional situation. In doing so, we have in mind mainly the Latin American context. However, since the basic forces behind this process are phenomenona of a generic nature (for example, the role of technological development in market economies), the discussion could also be taken as relevant to other regions of the developing world.

II. AGRICULTURAL MODERNIZATION AND INSTITUTIONAL CHANGE

The nature of the technology being generated and disseminated has important implications for the relative role of public and private sectors in technology development. In the early stages of development, the quasi-monopoly role played by public research institutions can be seen as a response to a practical reality: only the state could absorb the costs of research. These costs are initially:

- Relatively high due to lack of trained personnel and the absence of an adequate research infrastructure;

- At high risk due to lack of basic knowledge, markets of inadequate size, etc.;

- Difficult to recuperate, given that private appropriation of the benefits from research is uncertain, since a large proportion of the knowledge required refers to agronomic practices and simple technological know-how not associated with physical inputs.

Under these conditions, agricultural technology can be seen as a pure public good, and the institutional model that emerged was logically oriented to assure the supply of the needed technology and socialize research costs. The problem was viewed as one of transferring technologies from developed to developing countries, which required infrastructure capable of adapting available technologies to local conditions. This formed the conceptual basis for an important international assistance effort that supported the development of public research institutions, usually following the US Land Grant/Experimental Station System 3/.

As agricultural modernization progressed over the last three decades,a number of changes have taken place in the abovementioned initial conditions, setting the basis for increased interest and participation by the private sector in agricultural research and technology development.

The Public Sector Role in Development of Research, Infrastructure, and Human Resources

The initial efforts of The National Agricultural Research Systems (NARS) in Latin America, as well as in other parts of the world, were oriented toward the development of human resources and of basic knowledge of the countries' natural resources (soils maps, agroclimatic information, etc.), and other general information considered essential for the applied and adaptive research work they were mandated to undertake. Work in both of these areas was undertaken with extensive funding and technical support from the international

donor community (Trigo, 1986). The result of this process 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 had effects on the costs of R & D activities for the private sector. Private firms interested in developing R & D units did not have to confront the costs and time delays of training their own personnel, preferring instead 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 body of basic agricultural knowledge also lowered risks associated with R & D and even made possible work in other areas like agrochemical evaluations and fertilization.

Producer and Non-Governmental Organizations in Technology Generation and Transfer

Modernization and development have implied an ever-increasing importance of technology in the production decision making process, both in public and private spheres. In general, as the availability of previously unused land diminishes, technological change becomes the only alternative for increasing production. Moreover, the increased use of non-neutral technological inputs, in terms of their income distribution effects, has generated specific sectorial interests affecting the direction and intensity of the process of technological change.

This process has been accompanied by the development and consolidation of coorporative agricultural producer organizations and, more recently, non-governmental research foundations as important actors in the agricultural R & D process. Producer organizations are important in cases where homogeneous production structures (in terms of farm types and geographical concentration of production), prevail, and where the technological potential already exists.

The rice and sugar cane growers'associations in Colombia are good examples of how producer groups develop an increasing participation 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 initiated its rice activities in the early 1970s, creating a substantial "technological potential", the direct participation of FEDEARROZ became of real importance in a triangular partnership with CIAT and ICA. The sugar cane case is somewhat different, as the sugar cane 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 (CENICAÑA) is now formally mandated to undertake all sugar cane 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 funding of 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 Silva and Puiggros Planas, 1985).

Producer organization involvement in the adaptation and dissemination of technology has also become significant; in some cases, they have virtually assumed the role of the public extension systems throught 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 a total of 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 institutional development of importance is that of the research foundations. Within this group, it is necessary to distinguish between those which are 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 Fundacion Hondureña de Investigacion Agropecuaria, FHIA in Honduras, and Fundacion Chile are cases of the first type. Even though each one responds to a particular situation, all of them were created to mobilize available technological knowledge with a problem-solving orientation and a highly flexible, non-bureaucratic administrative structure. Although applied research is the core activity, they have very strong transfer programs, and in cases like the Fundacion Chile they go as far as the design and implementation of agro-industrial projects to exploit specific production potentials or market opportunities. Research-funding foundations are more recent initiatives and still in the development stage. The Fundacion Dominicana de Investigacion Agropecuaria in the Dominican Republic and FUNDAGRO in Ecuador belong to this group. In most cases, these Foundations developed as external donors seek to provide alternative sources of funding, but they still have to consolidate their operational modes and prove their long-term financial viability; most depend on external donor grants (primarily USAID).

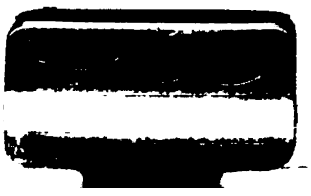
Regardless of whether they perform R & D activities themselves or are restricted to funding research, the foundations are important inasmuch as they represent a net addition to a country's research capabilities, as well as a way to widen the research support base. Potentiall, they can fill two critical niches in the technology generation and transfer process. The first is the need to link technology generation with the technology utilization stage, something that public institutions have not done efficiently; this is

particularly important for agroindustrial crops, but is also proving to be a critical function in the food crop situations, as some of the FUSAGRI experiences in regional development show 7/. Secondly, 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, but 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 of implementation, 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 activities. The most important are the opening and widening of previously non-existent or very limited markets for technological inputs. Several interrelated factors are involved. First is the trend for seeds, agrochemicals and machinery to acquire greater importance vis a vis 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 institutional inputs such as credit and technical assistance. Together with the growth of the commercial sector, modernization also brings about the development of the communication and service infrastructure necessary for getting the new inputs to the farm, thus expanding even further the markets for these inputs.

The market incentives for private participation in R & D activities derive from market growth and the lowering of input distribution costs (lower level of investments and shorter payback period) is further reinforced by the



possibility of property protection of the embodied technologies: the passage of plant breeders' rights legislation in a number of countries has extended this to seeds, while in the case of agrochemicals, machinery and veterinary products the patenting laws regulating the industrial and pharmaceutical sectors apply. Under these circumstances there has been a rapid growth of the seed, agrochemical, fertilizer and veterinary products industries, all of which have active R & D programs 8/.

This is neither new nor unique to the Latin American experience. The evolution of the United States' experience indicates a similar trend in its change from an initially primarily public system, implemented through the creation of the Land Grant Colleges and the USDA Experimental Station System, to the present situation, where about half of all agricultural research expenditures are defrayed by private firms.

In Latin America, and probably in other less developed regions, this process has gone beyond what regional and national modernization and developed conditions would warrant. This is largely due to the increased importance of multinational firms operating in these fields. Their multinational character has relaxed some of the market constraints because technological knowledge and innovations developed in one country can be used in another. The integration of national firms into multinational concerns also implies a differential access to technology potential; the larger scale of operations permits their direct participation in the generation of new basic knowledge (Trigo, 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 meeting the specifications of their industrial production processes and/or final markets (de Janvry, 1987). A number of important cases of this type of private sector involvement can be cited: the dairy industry in Argentina, where the large coops (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 experimental station to develop soybeans and maize varieties. In both cases, the initial R & D efforts lead to the creation of seed companies to market the products that were first developed for in-house raw material needs. The cases of vegetables and strawberries in Mexico are also important; however, in this situation R & D is part of the activities of the transnational corporations involved in the export of the fresh or frozen produce to the US market. This is also the case of a number of more recent initiatives in pineapples and other fruits in Central America developed as part of the "Caribbean Initiative", an export promotion program of the US government designed to facilitate export products from that region to the US markets. This form of participation can be expected to increase substantially as the percentage of agricultural production subject to processing before reaching its final market becomes higher, and as the efforts to diversify agricultural exports and increase their value-added content are intensified.

III. BIOTECHNOLOGY AND PRIVATIZATION OF AGRICULTURAL R & D ACTIVITIES

Biotechnology, together with microelectronics and new materials, constitutes one of the cornerstone of an emerging technological paradigm 9/. The development process of this field, while still incipient, is inexorable. As it picks up speed and plumbs new depths, it is significantly changing the scientific and institutional basis of agricultural technology generation and transfer.

Several aspects of these new developments are of importance for agricultural technology generation and transfer efforts in the developing countries. The first is that biotechnology is radically different than 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 the whole structure of linkages in the flow of scientific information. Clear evidence can be found, in developed as well as developing countries, in the of work now being done in biotechnological fields by universities and research centers with no previous experience in agricultural work 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 biotechnological work requires scientific talents different from those available at the traditional agricultural technology generation institutions. Eventually, the greatest obstacle preventing developing countries' research institutions from participating effectively in bictechnology may very well be their relative lack of personnel trained in molecular and cell biology, virology and immunology (de Janvry, 1987; IICA, 1987).

Following de Janvry (1987) it can be stressed that a second important facet of biotechnology is its relationship with the private sector. During the Green Revolution, most essential components were handled through public (international or national) institutions, whereas in the case of biotechnology the private sector, prompted by the proprietary essence of resulting technologies, is already an important force and probably will increase its presence in the future. Even though universities are playing an important role, the development of the biotechnology industry in the industrialized countries is characterized by market incentives and massive private investment, both from multinational corporations and from venture capitalists supporting small biotechnology firms. An indicator of the level of private sector involvement is that today there are 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). Further evidence of the importance of private sector involvement in

biotechnology can be seen in Table No. 1, which show the numbers of companies working in each area and market in the US.

It is not easy to assess the possible impact of the new biotechnologies on Third World agriculture. An indication, however, can be obtained from a cursory glance at the relevance that the techniques mentioned above hold for different food system markets. Table No. 2, by presenting this information, highlights an additional characteristic of biotechnology that sets it apart from the traditional approach: its non product-specific nature. Technology has traditionally been product-specific, a key factor in shaping the organization of agricultural research and technology generation; biotechnology, on the other hand, is process-based and cuts across products. This, plus its growing importance in raising present and future productivity in agriculture, will bring greater strength and new dimensions to the trend toward increasing private participation in agricultural R & D, as numerous factors work to produce a significant change in the industrial organization of the agricultural input business, with a greater cross-integration of inputs and more participation by transnational corporations. This characteristic is important to consider for the development of national strategies in this field (de Janvry, 1987; IICA, 1987).

IV. SOME ISSUES AND CONCERNS EMERGING FROM THE PRIVATIZATION OF RESEARCH AND TECHNOLOGY DEVELOPMENT

As we have mentioned above, the trend toward increased participation of the private sector in agricultural R & D activities is a result of a modification of the initial conditions that lead to the "public sector centered" institutional model prevailing in most of the developing world. In addition to institutional and market force changes associated with the modernization process, the advent of biotechnology and more exclusive patenting criteria have reinforced and broadened the trend. All these factors have definite policy and organizational consequences for the national agricultural research and technology transfer systems. In the remainder of

TABLE No. 1

NUMBERS OF U.S. COMPANIES IN SPECIFIC TECHNOLOGIES AND MARKETS

TECHNOLOGIES	MARKETS												
	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
Proc. 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
Recomb. DNA	58	87	16	44	80	17	33	15	4	28	70	17	52
Gene Synth.	8	11	3	4	11	2	3	3	3	4	13	3	8
Lg. Scale P.	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/US$	110	181	34	88	178	31	66	27	8	42	140	25	106

AG = agriculture, BL = biologicals, BM = biomass, CM = chemicals, DG = diagnostics, EM = energy, FP = food processing, FU = fuels, MN = minerals, PS = pesticides, PH = pharmaceuticals, TW = toxic waste processing, VT = veterinary.

Source: Riggs, 1985, presented in de Janvry, 1987.

TABLE No. 2

MARKETS AND BIOTECHNOLOGIES RELEVANT TO FOOD SYSTEMS

TECHNOLOGIES	MARKETS												
	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	

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.

Source: Riggs, 1985, presented in de Janvry, 1987.

this section, we briefly discuss some issues and concerns 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 as one of the dominant forces in the prevailing scientific paradigm has important consequences for the organization of scientific activity and the free flow of scientific knowledge. As the development of commercially relevant technical information comes closer to basic research activities, the traditional dichotomy between basic and applied research is significantly altered, and with it the nature and structure of the linkages for the flow of scientific information is also modified. Furthermore the increased possibility of patenting the results of research means that an increasingly important portion of the scientific knowledge being generated is going to be progressively 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 United States Land Grant System) and to the International Agricultural Research Centers for basic and strategic research results. They now find themselves in a situation where 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 the potential commercial value of the technologies that could be derived from it. 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 agricultural science and technology generation

systems of the developing world (Kenney, 1986). Actually, it could be said that the very logic behind the institutional nature of these research institutions it is substantially changed. Under the new circumstances, without easy and free access to basic and strategic scientific information, it is not clear how the NARS, designed as "technological convertors" for adapting to local conditions technologies available at the international level, could continue to perform their functions. Moscardi (1988) cites two direct problems NARS will have to confront are: (i) a relatively slow and increasingly costly access to new knowledge and specific technologies and (ii) the bias of new technologies in term of input use and relevance for local conditions. The latter is of special importance for tropical and subtropical areas (Moscardi, 1988).

TNCs Activities and National Technological Development

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

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

The first factor is the transnationalization of the originary seed companies as profitable markets were opened in the developing world. This

developed both through the creation of subsidiaries and by the taking over of already existing developing country seed firms. The sencond, and probably more important phenomenon is the acquisition of these firms by larger firms, mainly agrochemical, oil, grains trading and pharmaceutical companies. According to de Janvry (1987) this resulted from two separate, but interrelated forces.

On the one hand 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-products (Kenney, 1986). On the other hand is the passage of plant breeders' rights legislation in Europe in the early 1960s and 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 a obvious and optimal diversification road for these companies (Mooney, 1979). It now seems likely that virtually all of the seed companies will become centerpieces of large TNCs 12/.

In more recent times these companies, seeing the tremendous growth of the biotechnology industry, began to finance contract biotechnology research in the universities and in smaller start-up firms, and to invest relatively large sums in in-house R & D units, making the above process more active and vigorous.

From a general perspective the growing importance of TNCs in the agricultural technological supplies industries could be seen as a positive factor. To the extent that they are truly international corporations with research facilities around the world, the privatization of applied research may actually benefit the developing countries, particularly in the export markets, by giving them rapid access to state of the arts technology at the same time and price for everyone (de Janvry, 1987). This would remove part of the advantages that developed countries have in terms of early access to new

technologies but it would also raise a number of problems which need to be addressed.

First is a possible bias in research priorities toward the development and promotion of technological packages reflecting the corporations global strategies integrating seeds with their own herbicides and pesticides, rather than attempting to breed for genetic resistance to stresses, pests and diseases. This will lead to an increased dependance of agriculture on purchased, inputs which will have negative impacts on the competitiveness of small holder traditional farmers vis a vis large-commercial agriculture as well as on the environment.

Second, the expansion of the TNCs seed business could promote a further narrowing of the genetic base of important crops such as corn, wheat and sorghum, which would increase their vulnerability to changing environmental and ecological conditions, increasing the risks of widespread crop failures in many parts of the world.

Finally there would be the broader economic and food security implications of increased dependance on the TNCs marketing networks for strategic technological supplies. Capital intensive technologies run counter wise to the price relations prevailing in developing countries were natural resources and/or labor are relatively abundant vis a vis capital resources. At the same time many countries will place a high "political adjustment" factor in keeping national control on the supply of the strategic factors affecting 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 for continued development of national R & D capabilities together with clear policy definitions concerning TNCs participation in national agricultural supplies markets.

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 sectorial production; backward (input) and forward (processing/marketing) linkages assume greater importance. The specific nature of this process may differ from one place to another and from one commodity to another, but the general trend is usually the same: as agriculture and industry grow increasingly interdependent agricultural (farm) production should be viewed as one phase of the agroindustrial chain of production, and it becomes necessary to consider agricultural policies in general, and technological policies in particular, in the context of policies for industry and other sectors.

The tendency toward an increased private sector participation in agricultural R & D activities also implies the passage from a relatively centralized system to a highly diversified system conformed by components differing widely in their nature, objectives, size and behavior (producer organizations, public organizations, national input suppliers, foundations, transnational corporations, agroindustrial complexes, etc.). This situation raises the issue of how to integrate all these efforts into a coherent whole, making optimal use of opportunities and available resources.

The advent of the new biotechnologies also affects the scope of agricultural technology policies. As basic science grows closer to technology development, agricultural technology innovations need to be viewed in the broader context of the countries' overall policies for science and technology. Thus, policy-makers must consider agricultural research centers in concert with the whole complex of scientific and educational institutions involved in the development of the human resources and the knowledge base needed to enter and compete in new fields.

Technological policies for the agricultural sector have traditionally amounted to little more than decisions on the allocation of resources for research within the national public research institutions, with few thoughts of 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 priority-setting and resource-allocation process of 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 become more and more subject to the interplay of market forces. In this context the policies on agricultural inputs regulating the production and distribution of seeds, agrochemicals and farm machinery (price policies, patent and royalty regulations, foreign investment codes, etc.) can be expected to have a major impact on the technological behavior of the sector.

The potential contribution of technology to agricultural development and economic growth can be fully tapped only if these shortcomings can be resolved and full consideration given to the interdependence of different sectors and the impact of macroeconomic policies 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 research priorities and resource allocation decisions will be consistent with economic and agricultural policy, always taking into account the express concerns of organized representatives of agricultural interest. 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

Together with the emergence of new private (or at least non-public) sources of technological knowledge, we are witnessing a progressive deterioration of public sector research institutions. This situation could be seen mainly as a consequence of the budgetary restrictions derived from the debt crisis confronting the majority of the developing world and which severely affects the operational capacity of these organizations (operational budgets have been reduced to a minimum; resources for support programs like libraries and information systems, infrastructure maintenance and new investments have been eliminated; due to salary deterioration, it is increasingly difficult to retain highly trained personnel.) But it is also the result of a what is perceived as the organizations' ineffectiveness in reaching the farmers, particularly the smaller ones, and meeting their technological needs. Under these circumstances and, if the technological process is subject totally to market behavioral rules, 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 given the fact that in the developing world the agricultural sector is characterized by the coexistence of productive sectors at different stages of modernization. Within this structure, the increasing participation in the supply of technological services by private and semi-public sources, together with the deterioration of the public institutions, imply the potential widening of existing differences, as private sources will tend to service only those in the more advanced segments, with technological demands oriented to the capital inputs they offer. This point is important in relation to small producer and peasant economies in general; given their high heterogeneity in farm types and environment, they seldom represent profitable alternatives for the private sector. Moreover, they do not have the basic structural conditions necessary to facilitate producer organization development.

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 with respect to the non-modern sector and to undertake the scientific and technological knowledge development function needed for an effective technology generation process. In general terms it seems that an appropriate division of labor would focus public sectors institutions primarily on the generation and transfer of technologies for the small farm sector and those areas where either the size of the markets (small regions) or the nature of the technologies (-agronomic techniques, resource management research) offer no R & D cost recuperation possibilities. On the contrary, the private sector should be encouraged to undertake the development of embodied technologies where the proprietary nature permits cost recuperation. This broad division of labor, however, does not imply that the public sector should not continue working on basic or strategic research oriented to create "technological potential" or serve as "controls" 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 relationship with national programs. As with the national research institutions, the problems will involve linkages to the sources of basic scientific knowledge. As the "International Agricultural Research Regime" took shape, the bulk of funding came from the governments of developed countries and from philanthropic foundations. IARC scientists were at the forefront in establishing a free international flow of scientific information among researchers from a diversity of countries--north and south, socialist and capitalist, and so on. Because the private sector showed little interest, the limited resources of IARCs and of LDC governments had to be used for establishing input distribution networks and technology transfer systems. IARC scientists released new varieties as public-domain property--freely available at a nominal cost to anyone interested. Virtually all the needed external technical information was available as public-domain property from research institutes in developed countries, where the basic technical concepts had been long 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 institutes. They know that the information might at some point prove to be profitable. Private firms are pushing very hard to extend the provisions of the Plant Variety Protection Act and the patent and trade secret protections 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 the universities, where there is already a formal discussion about the right to patent 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 the greater restrictions on the free flow of scientific information (Buttel, 1986).

The Funding of R & D Activities

The institutional developments mentioned above open a key source of new funding for agricultural R & D activities. Private resources will be important in all cases since they will help widen the support base and free public resources for the undertaking of activities with externalities on the whole agricultural system while providing a closer link between funding responsibilities and the appropriation of the benefits of research. Furthermore, in the case of heavily indebted countries, attracting private

resources to the technology generation and transfer process represents probably one of the new ways 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 an easy task.

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 encounters hindrances to financing specific research projects in public research institutions. In turn, public sector scientists are often prevented from participating in private sector research and development of modern inputs. 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 due to the dominance of transnational corporations (TNCs), which 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 been taken to begin developing 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 tested the waters in 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 scientifists 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 "botton up" planning mechanisms and make them more responsive to final user needs, as well as to preserve the integrity, autonomy and social responsibility of 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 and will have a great impact on the countries' capabilities to exploit the potentials of new scientific developments, particularly the biotechnologies in the fields of agricultural inputs, and new market opportunities related to export diversification efforts.

In many countries, especially the smaller ones, TNCs already control input industries, and local firms are merely distributors of TNC products. Such being the case, 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, 1987; IICA, 1987).

Effective R & D support is also key in regard to new export market alternatives. Many such opportunities already exist, and 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 develop native capabilities for innovation.

V. SOME CONCLUDING COMMENTS

Over the last quarter of a century the technology generation and transfer institutions in the developing world 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 with better overall agricultural performances (Scobie, 1977; Moscardi, 1988).

Public agricultural research organizations have been at the center of a successful technological effort, and at the same time have been major contributors to the creation of the necessary conditions that will allow other private and non-public organizations to become active participants in the technological process. Scientific developments, particularly the advent of 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 other alternatives, particularly of private origin, including large TNCs operating in the agricultural inputs markets.

Parallel to these institutional developments, the debt crisis has had an important limiting effect on the operational capacity of national research organizations and their ability to continue 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 technological innovations. These changes will imply a redefinition of the scope of agricultural technological policies and the role that public sector institutions should play in the new context. There will also be a need to develop specific mechanisms to cope with issues like public-private sector interactions 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 during earlier periods, they still constitute the centerpiece of national agricultural science and technology capacities and will continue to play a key strategic role in the technological change process. The issue is how to adapt the model so to exploit the opportunities brought about by the modernization process and the diversity of new participants. The latest increased availability of international technical know-how 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 requiere proper consideration of the particular agroecological and socio-economic characteristics of each country.

FOOTNOTES

1/ The ideas and issues presented in this paper are developed on the basis of some of the author previous work (Trigo and Piñeiro, 1981; Piñeiro and Trigo, 1985; Trigo, 1986), as well as the work of others such as IICA, 1987; de Janvry, 1987; Moscardi, 1988. The author also wishes to acknowledge the contributions to the ideas presented in this paper by the staff of IICA's Technology Generation and Transfer Program, particularly Jorge Ardila, Eduardo Lindarte and Walter Jaffe.

2/ Director, Technology Generation and Transfer Program, IICA.

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 comolex 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 successvive 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), 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 (Piñeiro 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 present in the region as a whole:

- At EMBRAPA in Brazil, the total number of researchers between 1974 and 1985 grew from 872 to 1650, or at an annual rate of 5.96%.
- At ICA in Colombia the number of researchers between 1962 and 1988 went from 137 to 603, an annual rate of 5.86%.
- At INTA in Argentina the increase was from 640 researchers in 1958 to 1467 in 1978, an annual growth rate of 4.23%.
- At INIFAP in Mexico the growth rate between 1977 and 1985 was 9.7%, when the number of researchers went from 929 to 1949.

(Author's estimates on the basis of data from IICA and ISNAR publications).

5/ For an extensive discussion of this process in the cases of Argentina, Peru and Colombia see Trigo, E., Piñeiro, M. and Ardila, J., Organizacion de la Investigacion Agropecuaria en America Latina. 1982.

6/ For a more complete discussion of the case of the Research Foundations see Lindarte, E. Research Foundations in Latin America: An Institutional Approach, ISNAR, 1986.

7/ For a detailed discussion of the case of FUSAGRI see PROAGRO Paper No. 7. La Fundacion Servicio para el Agricultor en el Sistema Agricola Venezolano, 1986.

8/ An idea of the quantitative importance of market incentives can be obtained from the evolution of modern input consumption. For the whole of Latin America the proportion of the area sown to modern varieties of wheat and rice grew from 11 to 83 percent and from 4 to 28 percent respectively between 1970 and 1983 (Scobie, 1987). The fertilizer consumption index between 1979 and 1985 grew at about 13% per year in the case of nitrogen, 7% per year in the case of phosphatie and 13% per year in the case of potassium (FAO "Fertilizer Year book" 1976-1986); and the net trade of pesticides increased four-fold between 1970 and 1975 (de Janvry 1987).

9/ The principal techniques identified as "biotechnologies" are cell/tissue culture, cell fusion/hybridoma production, recombinart DNA techniques, gene synthesis, separatopm. 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 total number of 206 institutions included in the sample, only 51 or 24,6% could be classified as agricultural; of the, 106 responding institutions, only 39 or 36.8% were agricultural.

11/ The following table provides some figures of the extent of TNCs involvement in the seed industry and by extension of the level of crops input integration of the agro supplies industry.

INDUSTRIES	COUNTRY OF ORIGIN	ESTIMATED TURNOVER
Pioneer Hi-Bred (*)	USA	520
Royal Shell (oil)	UK/Netherlands	200-300
Sandoz (pharmaceuticals)	Switzerland	290
Lafarge Coppee/ORSAN Semences	France	200
Volvo Provendor (automotive) (Hilleshog/Weibull)	Sweden	170
Phizer/Dekalb (*) (pharmaceuticals/seeds)	USA	150
Upjohn/Asgrow (*) (pharmaceuticals/seeds)	USA	140
Ciba Geigy/Funk (chemicals/seeds)	USA	130
Lubrisol/Agrigenetics (chemicals/biotechnology)	USA	110
Cargill (agribusiness)	USA	80-100
Elf Aquitaine/Sanofi (oil/seeds)	France	90
Rhone Poulenc (chemicals)	France	n.a.
Monsanto (chemicals)	USA	n.a.
Occidental Oil (oil)	USA	n.a.
Atlantic Richfield ARCO Seeds (oil/seeds)	USA	n.a.
Continental Grain/ Pacific Seeds (agribusiness/seeds)	USA	n.a.

(*) Traditional seed company
n.a.= not available

12/ Basic research results, if not completely withdrawn from the public domain, will at least be delayed in their release until there is certainty that making them freely available does not diminish the possibilities for their commercial exploitation. The US Supreme Court decision Diamond vs. Chakrabarty in 1981 made it possible to patent novel living organisms and by doing so 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 passage of patent laws for seeds could be very farreaching. 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 for 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 case of seeds, where the industry is increasingly dominated by transnational corporations, many countries will want to have crop improvement programs capable of supporting the local production of improved seeds as a safeguard to oligopolistic behavior, excessive dependence on other countries and/or a bias toward the development of improved varieties with undesirable traits, such as excessive dependence on the use of agrochemicals.

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