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THE DEVELOPMENT OF THE PRIVATE SECTOR IN AGRICULTURAL RESEARCH: IMPLICATIONS FOR PUBLIC RESEARCH INSTITUTIONS

isnar

International Service for National Agricultural Research

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Of the thirteen centers in the CGIAR network, ISNAR is the only one which focuses primarily on national agricultural research issues. It provides advice to governments, upon request, on organization, planning, manpower development, staff requirements, financial and infrastructure requirements, and related matters, thus complementing the activities of other assistance agencies. Additionally, ISNAR has an active training and communications program which cooperates with national agricultural research programs in developing countries.

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PROAGRO SERIES

The Project on Agricultural Research Organization in Latin America (PROAGRO) is a collaborative effort between ISNAR, the International Research Development Centre (IDRC) of Canada, which provides partial financial support, and a number of Latin American research institutions responsible for research activity implementation in the region. These are the Centro de Investigaciones Sociales Sobre el Estado y la Administracion (CISEA) in Argentina, a group of researchers associated with the University of Campinas in Brazil, the Latin American Faculty of Social Sciences (FLACSO) in Ecuador, and the Instituto de Estudios Superiores Sobre la Administracion (IESA), in Venezuela.

PROAGRO's ideas and methodological approach represent a continuation of the work initiated in the cooperative Research Project on Agricultural Technology in Latin America (PROTAAL), implemented under the sponsorship of the Inter-American Institute of Cooperation for Agriculture (IICA), between 1977 and 1983. The project's current focus is on the analysis of the role and impact of private agricultural research activities within the context of the research systems of the region.

This publication series is designed to diffuse PROAGRO's methodological approach and research results and will include publications in Spanish, Portuguese, and English, the project's three working languages. The opinions and points of view expressed in the papers are those of the authors and not necessarily those of ISNAR or other participating institutions.

Alexander von der Osten

Director General

ISNAR

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I. INTRODUCTION

Agricultural research in Latin America has been dominated by public research institutions. During the sixties and seventies, most countries developed national reseach institutes, which, in time, became important and relatively efficient research organizations. This institutional model, an innovation in itself, is relatively unique to the continent and probably represents an adequate response to a number of organizational and political characteristics of the countries in the region.

The last few years have witnessed an important process of agricultural modernization in the region which has resulted in an expansion of agricultural production and a growing use of agricultural inputs. This process of modernization has been accompanied by the development of private organizations that are mainly concerned with the production and/or distribution of technology. There is a vast number of different organizational forms, but probably the most important ones are related to the production of inputs, which are the basic elements of agricultural modernization (1).

The emergence of the private sector as an important carrier of technological innovations is closely associated with the nature of the innovations incorporated to the production system, which, in turn, are related to factor endowment, economic policies and the level of the economic development achieved in each country. However, in general terms, as modernization progresses, the dominant technologies are of the embodied type, which also require a more complex and sophisticated

research base. One consequence of this evolutionary perspective is that the main roles and functions of public research institutions, and consequently their organization and management style, must also evolve. Thus, research institutions must be seen from a dynamic and evolutionary perspective, in which it is recognized that they must constantly change and adapt themselves to their new roles.

A second consequence of the development of the private sector is that it has involved a considerable modification of the environment in which public institutions operate. First, the private sector became a source of competition for highly qualified researchers and in some cases for financial resources. Secondly, they also became a source of competition in the public eye, and in particular for special interest groups, which are important users of agricultural technology. As a consequence, in some instances, the political support received by public institutions has deteriorated, especially because they are no longer seen as the only possible and viable source of new technology.

The changing roles and potential deterioration of public research institutions, brought about by the development of the private sector, pose a number of important and difficult policy issues that need to be carefully analyzed and placed in an appropriate historical development perspective in order to draw practical implications for the organization and management of public research institutions.

This paper will briefly address some of these issues. In section II we will discuss the emergence of private research in relation to the observed cycles or stages of technical change and agricultural modernization. Section III will be devoted to the description of the

changing roles of public research institutions along the modernization process and the implications that this evolution has on organizational matters. Section IV will briefly discuss a number of issues related to the emergence of the private sector research. Finally, section V will summarize the significance of this discussion for technical assistance and institution building activities relating to national agricultural research institutions in the developing world.

II. THE EMERGENCE OF PRIVATE RESEARCH IN AN HISTORICAL PERSPECTIVE

Technical change in the agricultural sector requires a rather complex process, by which knowledge, human behavior and improved inputs merge in a productive way, resulting in productivity increases of natural resources and human labor.

The first two of these elements have been to a great extent the responsibility of the public sector, which, through research organizations and extension activities, has tried to promote technical change. In the case of agronomic practices, related to relatively simple agriculture, these two elements are the basis for achieving increases in factor productivity. However, as agricultural becomes more sophisticated, a large proportion of the new technological innovations will be embodied in industrial inputs which require a progressively more sophisticated industrial base as well as specialized distribution and financing mechanisms. Thus, in market economies where in general the state does not participate directly in the production of goods, technical change will progressively depend on the development of the industrial and services sector.

A. Technological Cycles

Recent works (2) suggest that, at least in Latin America, technical change in agriculture shows innovative cycles where each cycle is characterized by a dominant technology. In addition, the emergence and

sequential nature of some of these cycles seem to be partially explained by the development of industrial sectors which follows a certain logic within the process of capital accumulation in the overall economy. This process has special characteristics in each country and, consequently, the sequence of some of the cycles and their length will not necessarily be always the same. For example, in Argentina and Brazil, although a similar pattern can be observed, fertilizers became important in different stages of the modernization process.

In spite of these differences and for the purpose of this paper, it is possible to present a description of the general characteristics and sequential order of the technical cycles in Latin America.

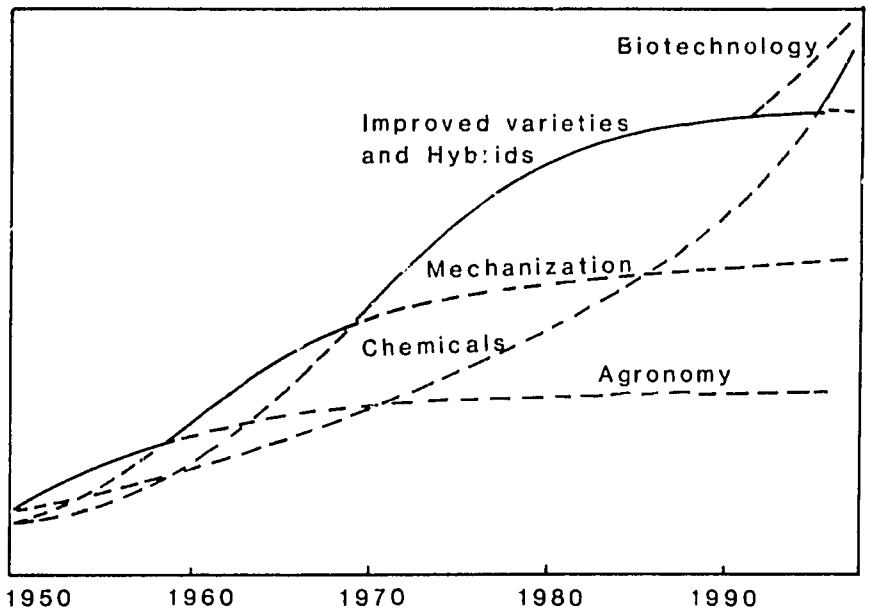
Figure 1 presents the sequential nature of the cycles and the dominant technology in each one of them. The timing corresponds, in a general way, to the more developed agriculture in Latin America, generally coincident with the temperate regions.

The first stage is charaterized by the diffusion of improved agronomic practices, many of them introduced from abroad, and others developed by local research institutions and the farmers themselves.

It is important to note that, because of the disembodied nature of these technologies, it is virtually impossible for those who create and diffuse them to capture the benefits derived from their use. Consequently, the public sector was the main source for the development and adaptation of these innovations. The weakness of public research institutions before the sixties probably explains the modest impact of these technologies

FIGURE 1.

Adoption of technologies and their contribution to production



and, consequently, the relative stagnation of agricultural production before the sixties.

The second stage is characterized by the diffusion of a number of powerful technologies that share the main characteristics of being of the embodied type: namely mechanization, improved seeds and agrochemicals. The order in which these technologies are incorporated into production depends on a number of factors. Mechanization and fertilization will be strongly affected by factor endowment and relative prices. For this reason they were rapidly adopted only under certain production conditions. On the other hand, improved seeds, which necessitate substantial research work for their adaptation to each specific ecological condition, required for their development the existence of a minimum research infrastructure in the country. Finally, the diffusion of pesticides and herbicides was closely related to the previous diffusion of highly productive varieties; to some extent to the late development of the more specific and effective agrochemicals in the developed world; and, to the development of a minimum industrial and distribution infrastructure in the developing countries (3).

This brief description only attempts to emphasize that the diffusion of embodied technologies is associated with three main factors: (a) the development of an adequate research infrastructure; (b) the development of a minimum necessary industrial and distribution infrastructure; and, (c) certain technological relationships between the dominant technologies.

Finally, it is also important to note that, as indicated in Figure 1, the more recent scientific discoveries in the general area of biotechnology could herald the possible emergence of a new stage in the technological

cycle, characterized by the utilization of research techniques that could radically alter the way in which research is done and in the productivity of agricultural technologies.

B. The evolving research needs and the emergence of the private sector

The complete process of invention and distribution of a technological innovation can be systematized into the following figure (4):

	FUNCTION	INSTITUTIONAL PRODUCT
1	Basic or fundamental research	Knowledge with unknown or unspecified utility
2	Strategic research	Development of practical uses of knowledge
3	Applied research	Product and technology development
4	Adaptative research	Adaptation of technologies & products to specific conditions or situations
5	Technology verification	Demonstration of practical use under real production conditions
6	Extension & diffusion	Diffusion of technologies to final users

It is important to note that the sequence is closely related, but in reverse order, to the major research needs associated to the technological cycles described in the previous section. Agronomic practices are closely associated to adaptative research and the verification and diffusion of technologies. As embodied technologies become more important, the innovative process will require a higher component of applied and strategic research which is directed at the

development of new products. Similarly, as technological packages become more complex and sophisticated, more strategic and basic research will be required to sustain the innovative process. This is particularly true of the development of biotechnology and other high technology components that are progressively becoming more important, and that could define a new technological cycle.

This argument suggests that as modernization process progresses, the research needs and consequently research demands exerted on the research system of any particular country will evolve in a more or less predictable manner. The research system will have to grow towards more sophisticated research in order to service the needs of the productive system.

Concurrently, the emergence of embodied technologies will - in market economies - advance the development of private sector institutions eager to capture the economic returns obtainable from the production and marketing of these embodied technologies. In order to do this the private sector will have to be willing and able to do substantial investments in research activities either alone or in connection with the parent firms in the developed world or to rely on the research done by the public sector.

It is this evolving nature of research needs that also imply a changing role for the public sector institutions.

III. THE CHANGING ROLE OF PUBLIC RESEARCH

A. Downstream (applied and adaptative) research

Public research institutions in Latin America were created with the mandate to concentrate their efforts on adaptative research. The basic perception was that these institutions could rely, for the most part, on the institutions of the developed world for the necessary work in strategic and basic research (5). This organizational philosophy, and the concentration of efforts in adaptative research, payed good dividends in a number of cases and the agricultural research institutions played an important role in initiating active processes of agricultural modernization.

Paradoxically, the implications of the organization format adopted, based mainly on departments along disciplinary lines, was that as the level of training improved, internal forces led to attempts to move to strategic research areas. However, in most instances there were insufficient scientific and physical facilities for the efforts to result in important scientific contributions.

In addition, in recent times, it is possible to observe in some cases a deterioration of research work directly related to product development, such as crop improvement programs. The causes for this centrifugal evolution lie probably in certain characteristics of their organizational structure which emphasize disciplines as opposed to multidisciplinary product oriented task forces as well as on the competition of the private

sector, primarily focused on these areas of research. For example, in the seed industry, dominated by transnational corporations, the headquarters concentrate on applied research and the subsidiaries on adaptative research. A similar functional structure, which has proved effective, is illustrated by the work of the international centers and their relationship with national programs.

Research activities by the private sector concentrate on the development and improvement of embodied or marketable technologies. It is here that the nature of the technology, and in some cases the patents or other legal protective mechanisms, guarantee the possibility of private appropriation of the benefits derived from successful research. Recent history shows that the large benefits that can be derived from agricultural technical change have attracted to this field some of the most powerful and dynamic firms, including transnational corporations which have dominated the markets for machinery, seeds and agrochemicals (see Obschatko, Jacobs & Gutiérrez for Argentina; Da Silva for Brazil).

The role of the public sector in the development of new technology of the embodied type has been minimal in farm machinery and agrochemicals (Obschatko, Da Silva). Their main activities have been in testing the effectivity of these technologies and making agronomic recommendations for their use. This role, together with their extension activities, were somewhat instrumental in their initial and rapid adoption of mechanization by farmers, but had no major relation to the actual development of the technologies or their improvement which have been mainly determined by the industries that produce them.

In the case of agrochemicals, the nature of the products, the complexity of the research and its relationship to other types of research (pharmaceutical) make highly unlikely that this situation will or should change (6). On the other hand, public research institutions have had, and still have, an important role in crop improvement including seed production and animal breeding and health protection.

The case of crop improvement is probably the most important situation, where the emerging private sector has become a competitor for the public sector in an activitiy that has great importance not only from a budgetary point of view, but because of the way research organizations are organized and operated. In some cases, crop improvement has been the backbone of agricultural research and public institutions can take the credit for the substantial successes.

Both in Argentina and Brazil the public sector was instrumental in the development of new varieties, incorporating the dwarf genes, and played an important role in the development of the early inbread lines with corn.

This important role has diminished quite dramatically in more recent times, especially in Argentina. The reasons for this lie both in the explicit policies of INTA (Gutiérrez) in the case of Argentina and in the competition and drainage of human resources that followed the establishment of the major private firms in both countries. However, it would seem that, as Gutiérrez has argued, there are a number of reasons why public research institutions must maintain, at least in the larger countries, a leading role in crop improvement programs. The most important of these reasons are:

a) Genetic and crop improvement work is the result of relatively long research processes which require a high level of commitment and perseverance. In addition, the type of research results produced do not always provide a basis for the preparation of publishable papers in professional journals. In this way, professional advancement and the personal satisfaction of intellectual production, associated with publishing, may be difficult to achieve. It is mainly for this reason that crop improvement specialists need to be in a position to carry their work through the last stages of the process, which implies the creation of new varieties or hybrid lines of proven practical value. To detain the research process at an earlier date would most likely result in the impossibility of having any type of creative crop improvement activities.

(b) Public institutions must provide improved varieties adapted to specific regional environments too small or difficult to attract private sector interest.

(c) If the private sector is dominated by transnational corporations, a number of countries will want to have crop improvement programs capable of sustaining the production of improved seeds to prevent oligopolistic behaviors, excessive dependence on other countries and/or a bias towards the development of improved varieties with undesirable traits, such as excessive dependence on the use of agrochemicals.

(d) Finally, the training of researchers in crop improvement activities is highly dependent on the practical experience that can only be

obtained through participation in a research program. Consequently, a minimum of public crop improvement is necessary as a complement to training activities.

B. Upstream (basic and strategic) research

1. Induced demands from the private sector

It has already been mentioned that national research institutions were created with an explicit mandate which placed the emphasis on adaptative research, and that this research strategy was successful in a number of cases, specially under temperate agriculture conditions which were relatively similar to those in the developed world and where the technological gap was quite wide. Now, after a quite intensive process of modernization, technological innovation has become more dependent on the resolution of problems which require autonomous research of considerable scientific complexity (7).

Although a large part of this research is done by institutions in the developed world, and more recently by the International Centers of the CGIAR System, there is a need for very specialized basic research oriented to the development of scientific knowledge. In addition, it is possible to argue that a balanced and effective research system requires some degree of basic research to maintain its dynamism. The question is who can and should do the needed upstream research in developing countries. It is quite obvious that the private sector will not be able to do it for a number of reasons. First, most of this research will not yield private benefits within a reasonable period of time and with acceptable levels of certainty. Secondly, it will require a sizeable

investment and an organizational complexity that young and weak private firms will not be able to sustain. Thirdly, as a large proportion of private firms are subsidiaries of transnational corporations, they will tend to rely - as a matter of general policy, and as they have done in the past - on the research capacity of parent firms (8).

The reasons why the private firms will not be in a position to actively pursue research projects directed to generating basic knowledge also suggest the two principle reasons why public research institutes should do it. First, in a number of countries where the Universities are weak, underfunded and have little tradition in research, there is probably no other institution capable of doing it. Secondly, if this research is not done as an explicit policy in support of the applied research developed by national private firms, the subsidiaries of transnationals will have a definite advantage over them in the development of new products and, consequently, in the market. In other words, national research institutions must provide the research support to national firms that transnational subsidiaries receive from their parent firms.

These considerations lead us to two important questions: What type of upstream research can reasonably be assigned to national research institutes? Should their work respond to specific demands emerging from clearly identified needs of the private sector that will develop the technology? If this is the case, should the knowledge be provided for free, or can the public institutions charge for it? The second question is: does this function require a special and different organizational structure than the present one? These questions are addressed in the following paragraphs.

2. Basic research in the national research institutes

The complexity of science contrasts with the relative weakness of public research institutions in most developing countries. Under these conditions, basic research would be like a drop of water in the desert, developed without clear objectives related to the generation of knowledge needed for the solution of previously identified and selected technological problems. In all probability, the results would be lost and become obsolete before finding their way to practical use. If this is the case, it seems natural that basic research should respond to clearly articulated demands from the final users of such knowledge, which, in many cases, will be the private sector which develops agricultural technology.

In this role, public institutions would be performing a service to these final users, and consequently subsidizing them, unless some type of cost sharing or profit participation arrangements are made. Probably the simplest method, and perhaps the only practical one, is for the public institutions to charge direct costs to the firms that request specific and identifiable research projects. In most other situations, where the knowledge produced does not have a direct and exclusive user, it may be necessary to accept the existence of a subsidy as part of the role of the public sector.

C. The changing roles of public sector research: organizational implications

We have argued that as agricultural modernization progresses,and especially as a consequence of the emergence of the private sector as a major source of agricultural technology, the roles of public research institutions must evolve. The general direction of this evolution is to move toward more upstream research activities and more specialized and selective research topics which have a natural complementarity with the applied research emphasized by the private sector.

This likely and desired evolution of public research has a number of important organizational consequences, derived from the fact that different research activities have some very distinct organizational requirements. Some of the more important of these are discussed below.

Adaptative research, characteristic of the early stages of agricultural modernization, is dominated by very practical research in agronomy and related fields. This research is best adapted to the work of individual researchers or, at best, small groups of researchers. It must be highly decentralized and developed close to production activities, nor does it require elaborate and sophisticated programming mechanisms, either to select research priorities or to organize the allocation of resources. As the focus of research institutions moves to applied research, including the development of technologies and products (seeds), the organization of research becomes more complex. Here, the concept of multidisciplinary teams organized around well-defined projects or programs and with a minimum critical mass becomes of fundamental

importance (9). Similarly, the selection of competitive research objectives makes it necessary to develop more sophisticated programming mechanisms to allow a rational and orderly allocation of resources.

Upstream research is further removed from the productive system and, consequently, not always is it possible to relate it to clearly enunciated objectives. It cannot be rigidly planned, because results will tend to be less predictable and the very nature of the activity requires a flexible, loose organization, that permits the continual redirection of research based on feedback from early results and the intuitions of the researcher. At this level, research results are more related to the imagination and perception of individual researchers than to the integrated and persistent work of interdisciplinary teams. For this reason, upstream research will require an organization that follows more closely disciplinary lines that do not require large and solidly structured teams or departments. It does require, however, an intellectual environment that provides for permanent and flexible mechanisms for consultation and discussion of ideas and hypotheses.

These and other organizational elements will have to be adapted and changed as research institutions move from adaptative to applied research, and, finally, towards upstream research. Similarly, the structure of newly created organizations should be fine-tuned to the level of development of the country in question and the type of research they are to concentrate on, given that level of development.

D. A special caveat: small farms and the concept of appropriate technology

The discussion of the two previous sections point to the evolution of agricultural modernization toward more sophisticated and complex innovations of the embodied type. This pattern of agricultural development is closely identified with the experience of the more developed and commercialized agriculture found in temperate Latin America and other regions of the continent.

However, throughout most of the concinent small farming, associated in some cases with a peasant type economic structure, is still important both numerically and in terms of their contribution to total food production. It is obvious that in those countries where this type of production is important, public research institutions must dedicate a substantial part of their research effort to developing technologies appropriate for these conditions, which are characterized by being very site specific, having low capital use and high concentration of labor and usually associated to small-sized farms.

Under these conditions, agronomic research of the most pure type is still the most important element that may lead to agricultural modernization. It is in this line of thought that the concept of appropriate technology has a new and positive meaning. Following the ideas of one of its main originators (Schumacher), appropriate technology is usually associated with small size and opposed to modernizing technology. But, if one recongnizes the evolutionary perspective implied by the existence of interrelated technological cycles, which are determined not only by

technical elements, but also by the level of development of agriculture and that of the general economy, then the concept of appropriate technology may be redefined to mean that a technology is appropriate if it is congruent with the level of development achieved in each particular case. The argument can be illustrated by saying that hybrid seeds are not appropriate until the country has a research and seed multiplication capacity for the production and distribution of seeds or that sophisticated farm machinery cannot be effectively utilized, if a distribution and service infrastructure has not been developed previously.

It is important to note that public research institutions that must dedicate a substantial part of their effort to the development of agronomic technologies in the early phases of the technological cycle will also need some specific organizational characteristics. The main point here is the capacity to work under multicrop rotations with tight restrictions in relation to capital and labor availability. Under these conditions, the capacity to identify the real production constraints and the interactive relationships between different crops and farming practices is of particular importance. Consequently, the organizational structure will have to give particular attention to interdisciplinary teams with regional responsibilities and relatively less attention to either more specialized crop improvement programs or disciplinary departments.

E. Public institutions: other non-research functions needed for achieving technical change

The growing importance of embodied technologies in the innovative process creates the need for the development of an industrial and services sector capable of producing and/or importing and distributing the wide array of technological inputs associated with agricultural modernization.

It is usually argued that in market economies the private sector will invest in those areas where new needs generate opportunities for private profits. This view is specially congruent with ideas now quite popular in Latin America regarding the existence of an overgrown government bureacracy and the convenience of relying on the private sector for the provision of all goods and services which are socially needed.

While analyzing this view, it is important to review the historical evidence regarding the overwhelming role that the public sector has played in most or all successful cases of economic development in Latin America. The point is that underdevelopment is characterized by a weak private sector, dominated by small business firms with low production technology and limited capacity to enter into high technology production areas. In many cases, the government is the only organization with the adequate economic and human resources, and organizational dimension to be able to start the production and distribution of technological inputs.

For this reason it is likely that in many cases, specially in small countries and/or small markets, a sustained modernization process will require government organizations to play an active role in the production

and distribution of technological inputs. This role might be temporary and complementary to the activities developed by the private sector, which in the end may become the main or only source for these inputs.

In most cases, if the government is to play this role, it will be necessary to create new organizations and institutional mechanisms pecially adapted for these activities and with special linkages with public research institutions from which they will depend for the provision of the necessary knowledge. It is through these linkages that the whole innovative process will be integrated into one institutional system.

IV. SOME ISSUES RELATED TO THE EMERGENCE OF PRIVATE SECTOR RESEARCH

A. Drainage of human resources

Research is based on the work of highly qualified persons who have undergone a long process of informal and formal training. For this reason they are scarce and, from a private sector point of view, represent a long and expensive investment.

One of the very important roles played by public research institutions has been the post-graduate training programs they initiated and to some extent funderd during the early years after their creation. For example, the Instituto Nacional de Tecnología Agropecuaria (INTA) in Argentina, the Instituto Colombiano Agropecuario (ICA) in Colombia and the Universidad Nacional Agraria La Molina in Peru, trained between 1960 and 1978, 276, 630 and 260 persons respectively. Other institutions, such as the Empresa Brasileira de Pesquisas Agropecuarias (EMBRAPA) in Brazil, the Instituto Nacional de Investigaciones Agrarias (INIA) in Mexico and the Fondo Nacional de Investigaciones Agropecuarias (FONAIAP) in Venezuela have made equally or more important efforts (10).

With the development of the private sector, a new and strong competition for those scarce and expensive human resources has developed. There are at least a few extreme and illustrative situations where the private sector has hired complete teams, including secretaries and specialized laborers (11). In these cases, hiring the researchers has the additional

advantage of indirectly buying research results from years of research work.

The policy of public research institutions in relation to this situation has to evolve out of both supply and demand considerations.

In Latin America, as in most other developing regions, public research institutions are governed by relatively fixed and restrictive salary conditions that correspond to general public service policies. In many cases the private sector will be willing to pay salaries and cash outlays considerably higher than those payed in the public sector. These payments are possible because they represent not only an investment against incomes derived from future research, but also the accumulated knowledge embodied in the researcher which is transferred to the private firm.

Given present salary conditions and the absence of more flexible hiring mechanisms to allow researchers to capture at least partial market value of their knowledge, it is clear that it will be difficult for the public sector to retain these researchers working in areas that result in marketable technologies (12).

In addition to salary considerations, a number of studies suggest that researchers strongly consider the institutional environment in which they work when they evaluate employment alternatives. Important elements in these considerations are the existence of institutional mechanisms that recognize and encourage successful researchers and the opportunities for further training and professional betterment (13).

From the supply side, the obvious conclusion that one must draw is that public research institutions in developing countries must be prepared to support training programs sufficiently large to compensate the high rotation of qualified personnel that they are likely to have as a consequence of the competition of a growing private sector. Although this suggestion could prove an expensive proposition, it is the only way to avoid a progressive depletion of research capacity in public research institions, as has actually happened in a number of cases in Latin America.

B. Political support for public research

National research institutes were created in Latin America with varied degrees of support from the agricultural sector. In a number of cases the political strength came from alliances between government and industrial sectors concerned with increasing agricultural productivity and/or agricultural exports. However, it is also true that once these were established and could show some useful results, the agricultural interests rallied behind them. This political support became, in most instances, a fundamental element in the capacity to attract public funding and other forms of administrative support necessary for the development and growth of the institutions.

It is important to note that because the institutes are not involved in teaching activities, they do not have a constituency beyond the agricultural producers, as is the case in other regions of the world. For this reason, political support has been closely associated to a

clearly perceived utility of the activities of the institution such as the generation of production technology and extension.

When the institutes were the sole, or at least the main, source of agricultural technology, their importance to the farm sector was self evident. However, as the private sector becomes an important source of technological inputs, including improved varieties, and in some cases the agronomy that goes with them, the role and importance of public research institutions become diffuse and less clear to the non-professional eye. Even if the national institutes provide important research components indispensable to the development of the technologies produced by the private sector, their ties with the farm sector will be weakened, and their main constituency will be less vocal in their support.

This problem has been observed in a number of countries and is unfortunately further aggravated by a deterioration in the research capacity of public research institutions (Trigo, Piñeiro & Ardila).

As most institutions are highly dependent on public funding through annual allocations, the development of a strong, committed constituency can become a prerequisite for survival.

One more or less obvious implication is the need to incorporate the principal beneficiaries of the work of the institution into its governance, either through formal councils or advisory committees, by which means they become involved and knowledgeable about the needs of the institution. This participation must be closely related to the particular social organization of the country.

A second element is that public research institutions must be prepared to dedicate some resources and efforts to the specific purpose of making themselves known, and selling an institutional image to the general public and the government itself. This is also an important argument for the research institutes to maintain strong programs in crop improvement and similar activities that result in the development of technologies and products of direct use to farmers and consequently identified with the work of these institutes.

V. SUMMARY AND CONCLUSIONS

In previous sections we have tried to establish the relationship between the nature of the modernization process, the emergence of the private sector and the necessary evolution on the role and organization of public research institutions.

The discussion presented is based on evidence provided by major countries in Latin America, but to some extent is more representative of the experience of the technologically more advanced agriculture in the temperate regions of South America. However, it is likely that this experience can shed light on the possible evolution of agriculture in other situations and countries together with the emerging research needs.

The characteristics of the modernization process and its implications on the institutional-organizational format of agricultural research systems have a number of important implications in relation to research policy. Some of the more important can be summarized as follows:

a) In Latin America, specially in the larger countries, public research institutions were created in the sixties at a time when most of their agricultural production was still based on a low use of industrial inputs. The newly created research institutions had an important role in creating and diffusing improved agronomic practices and making foundations for a more modernized agricultre much more dependant on embodied technologies related to inputs of industrial

origin. Thus, the development of the private sector which produces these inputs is more recent, and, to a certain degree, a consequence of the work developed by the public research institutions in previous years, especially in adaptative research and extension. The apparent sequence of these two phenomena and the time lag between them may be different in some countries as a consequence of the international transference of technology carried out by multinational firms.

b) When embodied technologies become important in the modernization process, research and extension are insufficient instruments for promoting and sustaining it. The production (or importation) and distribution of inputs is a necessary condition, which in turn requires a certain degree of socio-economic organization, before it can be effectively performed. This point provides a new perspective to the concept of appropriate technologies. To date, discussions on this concept have been founded on elements related explicitely to the size of farms, and implicitely to farmers' behavioral traits and/or their financial capacity. It seems to us, that more important is the overall capacity of the country to produce (import), distribute and service the technological inputs, which are the main sources of innovation once the initial periods of agricultural modernization have been overcome.

It is important to note that some technologies, for example seeds, will be closely associated to the local research and distribution capacity, while others, like mechanization, will be directly related to the development of an industrial base, capable of producing, or at least servicing at a reasonable cost the machinery being utilized by the farmers.

c) In countries that are late-comers into agricultural modernization, the public sector has a strong responsibility in the development of organizational mechanisms, public and/or private, capable of making technological inputs available to farmers. In some cases, specially in countries where agriculture is similar to that in more developed countries, this role can be as important as the development of public research institutions.

d) A final point concerns the organization and functions of public research institutions. If technical change must follow a sequence at least partially determined by the development and progressive sophistication of the industrial and services sectors, then it would seem that agricultural research should be fine-tuned into this overall framework, evolving and adjusting its research priorities in a coherent way to the changes that take place in the agricultural sector and in the rest of the economy. This means that public research institutions will have to concentrate on certain research areas, depending on their level of modernization and development of their country's industrial sector. Furthermore, as different types of research require different organizational structures, public research institutions may need to create in-built adaptation mechanisms to be able to remain flexible and adjust to the level of modernization and economic development in the industrial sector.

FOOTNOTES

(1) PIÑEIRO (November 1983).

(2) PIÑEIRO (October 1984).

(3) For a more detailed description of cycles, see PIÑEIRO (October 1984).

(4) Modified from MCDERMOTT.

(5) TRIGO, PIÑEIRO and SABATO (1983).

(6) However, the public sector must fulfil an important role in quality control, agronomic recommendations and environmental control.

(7) For a discussion of the relationship between science and technology, see RUTTAN (1981) and KISLEV (1977).

(8) In some cases, firms will be anxious to investigate problems important to the subsidiary, but not to the conglomerate as a whole.

(9) The concept of large interdisciplinary teams with clearly defined research objectives was initiated with what was later called 'big science', the best known example being the Manhattan project that resulted in the development of the atomic bomb. Close and well-known examples are the crop improvement programs of the international centers of the CGIAR System.

(10) TRIGO, PIÑEIRO & ARDILA (1982).

(11) For example, in Argentina a seed company hired from INTA the complete team in charge of one of the major crop improvement programs.

(12) A possible solution to this problem is to allow flexible leaves for consulting. Brazil and Argentina have experimented with this type of solution.

(13) TRIGO, PIÑEIRO & ARDILA (1982).

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