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DYNAMICS OF AGRICULTURAL RESEARCH ORGANIZATION IN LATIN AMERICA

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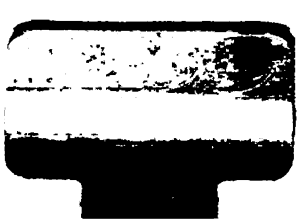

Dynamics of agricultural research organization in Latin America

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The authors summarize the conditions that led to the development of national research institutes in Latin America and to the creation of the international centres of agricultural research. The authors review the modernization process of the agricultural sector and the role played by public and international organizations in the appearance of non-public research. The authors discuss the impact of these institutional developments on the effectiveness of national research institutes, and the implications for agricultural science, technology policy, and the organization of agricultural research in the Third World.

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Scientific discovery and the resulting innovative process 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 for development of mechanisms that will allow for an adequate social control of the direction and intensity of technical change.[1]

In Latin America, and probably elsewhere in the less developed world, the discussion of this subject and the policy implemented have mainly revolved around the creation and organization 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 which has taken place 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. With the national institutions, these organizations form multi-organizational systems that have replaced the state monopoly that existed at the beginning of the 1960s.

In capitalist states, the development of non-public research institutions is an integral part of the agricultural modernization process. These developments are determined primarily by the creation of necessary preconditions in relation to the demand for technological inputs, production organization, the appearance and organization of social sectors with economic interests in technical change, and the development of 'technological potential'.[2] The development of multi-organizational research systems implies the progressive deterioration of public institutions and their relegation to subsidiary roles, mainly aimed at legitimizing the basic functions of the state.[3] These factors have profound implications for the organization of research and the orientation of technological innovation within the context of national development strategies.

Agricultural technology as a social issue

Research activities and technical change in Latin American

[1] In a previous article, the authors described the influence of social sectors on the behaviour of public institutions (M. Piñeiro, E. Trigo, and R. Fiorentino, 'Technical change in Latin American agriculture', *Food Policy*, Vol 4, No 3, August 1979, pp 169-177).

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agricultural production have been in evidence since the beginning of the century.[4] Examples include the rapid cattle cross-breeding process in the Rio de la Plata Basin and the development of cattle ranches specialized in the selection of breeds; the incorporation and adaptations of imported grain varieties and improvements in cultivation practices in a number of subtropical species. At the same time, the public sector began to participate in the process of generating technology in a number of countries through their ministries of agriculture.

Nevertheless, in the middle of the 1950s, a series of factors substantially altered the form and intensity of state participation in research activities. The main modification was the creation of decentralized, autonomous institutes generally organized on the basis of the experience derived from the Experimental Station System of the USA.[5]

Thus, with some organizational differences but within the same general model, INTA was created in Argentina in 1957, INIAP in Ecuador in 1959, INIA in México in 1961, ICA in Colombia in 1962 and INIA in Chile in 1964.[6]

The rationale behind the creation of these research institutes was that, in the absence of private research efforts, they were the most efficient institutional arrangement for the development of research which, on the basis of scientific and technological knowledge available from developed countries, could result in the creation and adaptation of new technological innovations.[7]

It is interesting to note that the sequence in the creation of these decentralized institutes, with the possible exceptions of Brazil and Ecuador, corresponds to the degree of industrial development achieved.[8]

Therefore, it is reasonable to hypothesize that the social forces necessary for this initiative are present only after industrial development has occurred and where, as a result, the social structure has progressed to the point where the interests of the urban sectors in forcing food production increases carried significant weight with regard to state decisions.[9]

This political weight was utilized to force the state to absorb the costs of research which were initially:

- relatively high, due to the lack of trained personnel and the absence of an adequate research infrastructure;
- associated to high risks due to the lack of knowledge, absence of markets of adequate size, etc;
- difficult to recuperate, given that private appropriation of the benefits from research was uncertain because a large proportion of the knowledge required referred to agronomic practices and simple technological know-how not associated to capital inputs.

Under these conditions, technology had the characteristics of a pure public good and consequently, the rational behaviour of the dominant socioeconomic groups was to assure the socialization of research costs.[10]

During their first decade the research institutions were mainly concerned with the training of research personnel, the development of basic infrastructures and the adaptation of technology developed elsewhere (fourth stage of the sequence described in Reference 7).[11] Only after this initial stage was completed was it possible for the national institutes to begin evolving more ambitious and complex

[2] Evenson uses the term 'technological potential' to describe the process of creating basic knowledge, the development of institutions and the training of personnel, which are three requirements for the development of technology (R. Evenson, 'Comparative evidence on returns to investments in national and international research institutions', in *Resource Allocation and Productivity in National and International Research*, University of Minnesota Press, Minneapolis, MN, 1977).

[3] O'Connor argues that the capitalist state must perform activities to release social tension to legitimize the basic exploitive nature of the economic system. (J. O'Connor, *The Fiscal Crisis of the State*, St Martin's Press, New York, 1973).

[4] A. Samper, 'National systems of agricultural research in Latin America', in *Potentials for Cooperation Among National Agricultural Research System*, Bellagio, Italy, 1977.

[5] These ideas are summarized by T.W. Schultz in his book *Modernizing Traditional Agriculture*, and served as the basis for the development of the foreign assistance policies of the USA, such as Point IV, implemented as of 1951. For a discussion on the subject see E. Trigo, M. Piñeiro, and J. Ardila, 'Modelos de generación tecnológica en América Latina: notas para una evaluación crítica', *Desarrollo Rural en las Américas Costa Rica*, Vol 11, No 2, May/August 1979.

[6] More recently, in the 1970s EMBRAPA has been created in Brazil, FONAIAP in Venezuela, INTA in Nicaragua, ICTA in Guatemala, INICA in Perú, and IBTA in Bolivia. The Venezuelan and Peruvian cases represent, for this period, some important differences in this model. In the former, the difference lies in the significant participation of the private sector through foundations like FUSAGRI, etc. In the latter, the active participation of the Agricultural University of La Molina in the innovative process is noteworthy. The decentralization process was not limited to technological institutions, as it also affected other service areas like marketing, credit, etc, and was complemented with the creation of sectorial planning offices responsible for the overall coordination of sectorial policies.

[7] Research in science and technology is complex, involving a series of interrelated steps, all of which must be performed if a final product (new knowledge) is to be obtained. Four main functions can be identified: *scientific knowledge* is associated with basic research, and focuses on expanding the knowledge frontier; *technological knowledge* is the adaptation and further development of scientific knowledge for its direct application to the development of a specific technological innovation – eg, the discovery of the hybrid vigor in corn and the development of the methodology necessary for the creation of commercial varieties;

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technological innovation refers to the creation of new (or better) inputs or capital goods or to the development of new (or better) productive processes – eg, the development of new commercial varieties of corn, the creation of new fertilizer, the development of a method of artificial insemination or an irrigation technique; *selection, testing and adaptation of the available technological innovations to each particular situation*. This can be broken down into different levels. These have to be adapted to each ecological zone, with possible successive approximations, and finally to the level of the particular productive unit. For example, the testing and selection of a specific variety of corn or the determination of the optimal use of fertilizers. As Evenson and others have pointed out, these steps have a complex interdependence, the nature of which explains the productivity cycles which have been observed in a number of products. Furthermore, the institutional arrangements required for the development of these research functions are quite different.

[8] Lower food prices and liberation of labour resources, as well as new or increased demand for the rising production potential of the emerging industrial sector, are usually mentioned as the contributions of agriculture to industrialization processes. All three are directly related to technological change in agricultural production. Moreover, in some countries, such as Argentina where the possibilities of horizontal expansion of agricultural production were exhausted, technological incorporation was the only valid route to increase the agricultural exportable surpluses needed to generate the foreign exchange required to finance industrial development projects.

[9] This argument in no way belittles the contribution of international organizations like ECCA and the Ford and Rockefeller Foundations to this process. On the contrary, it seeks to emphasize the fact that foreign initiatives were oriented and were successful in these countries where agricultural technology had become, as a consequence of its industrial development, an important social issue. For a discussion of this topic, see Piñeiro, Trigo and Fiorentino, *op cit*, Ref 1.

[10] It will be argued that overall modernization of the agricultural sector together with pioneering public sector actions to create basic technology and to develop necessary infrastructure, will eventually modify these conditions. As technology becomes a product capable of having market value (a merchandize) and markets for technological inputs grow large enough, the rapid recuperation of initial investments in research and development becomes possible. These conditions will encourage private investment and increase its capability to enter research and development activities.

research objectives related to the development of technological know-how.[12]

Almost simultaneously with the development of national research systems, international interest began to focus on the 'international centres'. The interest and rationale behind this idea was basically related to the need to rapidly develop technological know-how in basic food crops; given its wide applicability, this could then be used by national research institutes to help develop site specific technical innovations.

The research system thus created was logical, at least in principle, in the sense that the whole process of knowledge creation could be adequately performed. Scientific knowledge would be created by academic institutions of the developed world and technological knowledge in basic food crops would be generated by the system of international centres. The national institutes would be responsible for the generation of technical knowledge for the remaining products, as well as for the development of necessary technological innovations, their adaptation to each ecological niche and, in most cases, for their diffusion into the production system through the use of extension services – in this case, for all of the agricultural products.

The comprehensiveness of the system and the successful experience of most countries in the developed world in previous decades, suggested an optimistic outlook regarding food production and rural development in Latin America.

It is quite clear that the institutional system developed has had a considerable impact on food production in the continent. Worthy of note are the considerable increases in yield and production in rice in Colombia, wheat in Mexico, corn in Argentina, and soybeans in Brazil and Argentina. However, it is also quite evident that the degree of success has been uneven between crops and countries, and that the majority of the success stories have by-passed the small-scale producers.[13]

In addition, the institutional characteristics of development that have evolved over the last decades have had profound implications for research organizations in general and with regard to the effectiveness of public research institutions as the central component of the system.

Modernization and institutional change

The process of modernization

We have shown that research and technology generation for the agricultural sector was undertaken, particularly in the early stages of agricultural development, by public organizations. The modernization process, however, has implied a modification of some of the initial conditions that led to this situation specially in relation to market incentives.

In this sense, the most important aspect is the growing dominance of capitalistic production relations in agricultural production, a trend with definite implications for the opening of previously non-existent or restricted input markets.

This tendency is strengthened by the fact that products mainly produced by the capitalist sector, grow at a much faster rate than those of the peasant sector and that the farmer, probably as a consequence of its better access to institutional inputs such as credit and technical

Table 1. Nitrogen and phosphorus consumption per hectare of arable land and land under permanent crops in Latin America, 1961/65 to 1977/78.

Country	Nitrogen fertilizers (kg per ha)		Phosphorus fertilizers (kg per ha)	
	1961/65	1977/78	1961/65	1977/78
Fertilizer producers				
Brazil	1.9	16.9	2.8	37.7
Mexico	8.0	34.2	2.1	9.4
Chile	6.0	6.9	13.4	9.5
Trinidad and Tobago	22.1	22.1	3.9	1.9
Colombia	7.8	28.2	9.5	13.6
Venezuela	2.5	27.7	1.2	10.0
Argentina	0.6	1.2	0.2	0.9
Costa Rica	49.5	59.2	9.3	24.5
Peru	27.6	31.2	10.3	5.3
El Salvador	32.5	105.5	10.5	34.6
Cuba	28.4	70.8	28.0	17.5
Guatemala	6.4	34.1	3.5	14.9
Jamaica	32.5	17.0	8.3	16.2
Ecuador	2.2	11.4	1.8	4.5
Uruguay	4.4	9.3	10.9	22.1
Countries exclusively importing fertilizers				
Honduras	8.1	16.6	0.6	6.0
Nicaragua	9.5	23.9	2.5	10.1
Haiti	0.1	1.8	–	0.8
Dominican Republic	9.9	31.3	1.2	12.8
Panama	15.7	15.9	–	11.0
Bolivia	0.3	0.6	0.3	0.5
Paraguay	0.2	0.3	0.9	0.6
Latin America	5.1	18.0	3.4	15.6
USA	8.9	48.2	6.8	24.6
Japan	122.3	138.2	82.2	149.8
FR Germany	53.7	165.3	52.3	109.0

Source: P.C. Alvarez, unpublished data and summary on fertilizer trends, 1978, Mimeo.

assistance, has increased its use of technological inputs more rapidly than the peasant sector.[14]

These developments implicit in the modernization process, forced the opening of previously non-existent input markets. Also as development progresses, links between the agricultural sector and the rest of the economy are strengthened. This brings about development of the communications and services infrastructure necessary for getting the new inputs to the farms, thus expanding even further the market for new, modern products and inputs.[15]

The total impact of this very complex process can be illustrated by the changes in fertilizer use between the period 1961/65 and 1977/78 for a sample of selected countries and Latin America as a whole (Table 1). It can be seen that fertilizer use increased by almost 400% during this period, an increase lower than the one experienced by USA, but higher than that of Japan or Germany.

With this change in market conditions, the development process also modified the availability of technology potential at a national level, either by developing national capabilities – the original public sector organization – or through improved linkages with the international technology generation system.[16]

These processes affected all three elements conditioning the interest of the private sector to participate in the technology generation process: market prices, investment level, pay-back period. This applies, especially, to those research activities directed toward the development of capital-embodied technologies.[17]

Modernization brought about two main changes in the

[11] An example of the training activities developed by research institutions is given by the fact that, over the whole period, ICA trained 630 people and INTA 314 both at the MSc and PhD levels in different field of the agricultural and related sciences. Of these, between 25% and 30% left the organization, mostly during the late 1970s. A high proportion of these people (43% at ICA and 33% in INTA) left to work in private organizations. This illustrates how the national institutes contributed to the conditions and profitability of private sector involvement in agricultural research and technology development. For further analysis, see J. Ardila, E. Trigo, and M. Piñeiro, *Sistemas nacionales de investigación agropecuaria en América Latina: análisis comparativo de los recursos humanos en paises seleccionados: Los casos de Colombia, Argentina y Perú*, Instituto Interamericano de Ciencias Agricolas, Colombia, Documento PROTAAL No 50, 1980.

[12] *Op cit*, Ref 7.

[13] E. Trigo, M. Piñeiro and R. Fiorentino, 'Notas para el análisis de los instrumentos y contenido de la política technológica para el sector agropecuario', *Desarrollo Rural en las Americas*, Vol 10, No 3, September/December 1978, pp 153-172.

[14] A. De Janvry, and L. Crouch. Technological change and peasants in

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organizational structure of agricultural research in Latin America. Both limit or diminish the centrality of the national research institutes. However, they differ from each other in nature and evolve from different aspects of the development and modernization processes, and consequently will be discussed separately.[18]

The participation of private enterprise

The changes in market conditions described above imply increased private interest in participating in the research and development process for agricultural inputs. The evolution of Latin America's agricultural research organization follows this general tendency. Over the past 20 years, Latin American research systems have evolved from an initial stage of state monopolies to a system of shared responsibilities among the public and private sectors. The seed, agrochemical and fertilizer, as well as veterinary product industries, represent major examples of private enterprises's increased participation in the supply of technology.[19]

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 position where about half of all agricultural research expenditures are defrayed by private firms.[20]

In Latin America, and probably in other less developed regions, this process has developed beyond what regional and national modernization and development 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 implied a differential access to technology potential through their larger scale of operation which also permitted their direct participation in the generation of new basic knowledge.

Producer organizations and technology generation and transfer

Modernization and development have implied an ever increasing importance of technology in the production decision making process, both at social and private levels. In general, as the availability of previously unused land diminishes, technological change becomes the only alternative for increasing production. Moreover, the increased use of technological inputs of non-neutral nature, in terms of their distributional effect, has generated specific sectoral interests as to the direction and intensity of the process of technological change.

This process has been accompanied by the development and consolidation of corporate agricultural producer organizations, particularly in cases where homogeneous production structures prevail in terms of farm types and the geographical concentration of production. All of these elements have prompted certain primary production groups to assume direct control of the technological process, particularly in those countries and production situations where a level of technology potential already exists and which can be exploited through applied research direct at selecting and adapting available technological innovations.[21]

Examples of this type of institutional development are mostly

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Latin America', IICA, Costa Rica, Documento PROTAAL No 56, 1980.

[15] A. Hirshman, A generalized linkage approach to development, with special reference to staples. Economic Development and Cultural Change, Vol 25, supplement 1977.

[16] This process goes along with shifts in the supply of trained human resources at all levels, thus removing one of the critical limiting factors for the development of the technology generation process.

[17] Even though profitability conditions are essentially related to new inputs private concerns will also eventually enter into activities directed to improving the marketing of physical inputs.

[18] A more complete discussion of this aspect may be found in E. Trigo, M. Piñeiro and J. Ardila, 'Aspectos institucionales de la investigación agropecuaria en América Latina: problemas y perspectivas', *Desarrollo Rural en las Américas*, Vol 11, No 2, January-April 1980, pp 3-25.

[19] L. Marcano, 'Rol de las empresas privadas y multinacionales en la creación y diffusion de la tecnologia agricola', in *Seminario Sobre los Aspectos Socioeconómicos de la Investigación Agricola en los Paises en Desarrollo*, Chile, 1979. S.M. Sehgal, 'Private sector international research: the genetic supply industry', in *Resource Allocation and Productivity in National and International Agricultural Research*, University of Minnesota Press, Minneapolis, MN, 1977.

[20] V.W. Ruttan, 'Institutional innovations', in Theodore W. Schultz, ed, *Distortions of Agricultural Incentives* Indiana University Press, Bloomington, IN, 1978; V.W. Ruttan, 'The international centers of agricultural research and modification and comparative advantages', in *Seminario Sobre los Aspectos Socio-económicos de la Investigación Agricola en los Paises en Desarrollo*, Santiago, Chile, 1979.

[21] The availability of technology potential is the result of previous work by the national (public) research infrastructure, the International Center of agricultural Research and direct links with foreign research institutions.

related, although not limited, to product–producer organizations such as the Colombian Rice Producer Association or the Colombian Sugar Cane Producer Association.[22]

The Regional Agricultural Experimentation Consortium (CREA) in Argentina represents a different experience where regional and farm-type homogeneity are the guiding elements. This experience, which has recently spread to Chile, Uruguay and Southern Brazil, is also of interest for two additional reasons.[23]

First, these consortiums did not evolve from previously existing producer organizations; they were created specifically to speed up technological adoption, through cooperation among the participating farmers. Secondly, their main activities are not directed to developing technological inputs but rather to selecting and adapting innovations for improving production processes.

Impact on national research institutions

We have argued that the process of modernization in the agricultural sector implies, in market economies, the appearance and progressive expansion of private research organizations. This process of institutional change has a number of indirect effects on the role and effectiveness of the public sector in agricultural research. The most important are: the internal contradiction that national research institutions develop in response to the appearance of private sector research activities and the direct consequence of this process in relation to their stability; the growing difficulties in obtaining adequate technological services experienced by those sectors that do not have fully developed capitalist production relations; and, the progressive independence of the technological process of social controls other than the market mechanism.

During the initial stages of development of the technology generation system, national research institutes became, even in the absence of explicit policy decisions in this direction, *de facto* monopolies in the area of technology generation.

However, as the modernization process advanced, these institutes increasingly found themselves coming into conflict. As demand expanded and new organizations were ready to fill specific segments of this demand, the system evolved rapidly toward a multiorganizational structure where organizations ended up competing for resources and clientele.

This competition is particularly important in the case of national institutes in each of the areas of research which they are supposed to cover, when confronted by other, more highly specialized organizations: the international centres in the creation of technological knowledge of basic food crops; the private industry in the development of technological innovations specially of the capital-embodied types; and, producer organizations in the selection and adaption of available technology.

A consequence of this competition and the resulting social pressures that the process generates, is the progressive specialization of national research institutions in those areas of research which are of little interest to the more specialized organizations. An area of special importance refers to the satisfaction of small farmer technological requirements, a task which is not only difficult but also commands little real political support from the agricultural sector.

[22] Both cases represented are evolutions of institutional developments that evolve into the technology generation activities as the final stage of sectorial organizational processes. However, even though they are similar, particularly in the characteristics of the homogeneity of producers and the geographical concentration of production, they have some important differences. The most important is the type of producers predominant in each situation. Sugar production is organized with a high degree of vertical integration between cane production and sugar processing; technology generation activities appear as a final stage of the industry cartelization process once other aspects, such as pricing and export quotas, have been agreed. In rice production, organization and participation in technology generation is related to developments external to the industry itself, such as the presence of an international centre (CIAT) concerned with generation of new rice varieties and other technological knowledge. See M. Piñeiro, *et al, El Proceso de Generación Difusión y Adopción de Tecnología en la Producción Azucarera de Colombia*, Documento PROTAAL No 37, Costa Rica, Instituto Interamerican de Ciencias, Agricolas, 1979, Chap 6.

[23] N. Reichart, 'Análisis crítico de los diversos enfoques o sistemas de transferencia de tecnología agrícola en América Latina', in Angel Marzocca, ed, *Seminario sobre Transferencia de Tecnología Agropecuaria*, Uruguay, Instituto Interamericano de Ciencias Agrícolas, 1976.

At the same time, the increasing involvement in rural development implies a reduction in the relative importance of research activities and the need for a structural reorganization to cope with the new demands.[24]

This process may be responsible for the budget and personnel problems that some of the oldest national institutes in the region have faced over the past decade.

INTA in Argentina and ICA in Colombia are clear examples in both respects. Budgets in both organizations grew steadily from 1965 to the initial years of the following decade. In INTA, total budget figures more than doubled in real terms from $19.6 million in 1966, to $39.1 million (1977 $) in 1974, only to drop to $29.2 million in 1977. The case of ICA in Colombia is, in this respect, even more dramatic with tremendous growth from 1966 to 1972 when it rose from $5 million to $36 million, to drop abruptly to $24 million in 1978.

Training programmes in these countries showed a similar pattern with steady growth up to 1972/73 when personnel initiating postgraduate training reached its peak with 39 and 110 staff respectively, to decrease to almost zero in 1978. Total stock of trained human resources continued to grow in the later years of the decade as a consequence of the lag introduced by the trained personnel returning to the institutions, but shows a stagnation in growth rate from 1974/75 on, starting to decrease around 1978.[25]

The deterioration of the national research institutes can also be observed from the fact that during this period they suffered constant changes in their internal organization structure. These processes, however, did not evolve from changes in the original by-laws but rather from internal efforts to adjust to the new and changing external conditions they had to face. This has represented an extra source of conflict and isolation as the new structures often implied prioritization of new activities and clientele that were not previously represented in the structures of the organization's governing bodies.[26]

This process of deterioration of the national research institutes reaffirms the progressive specialization of the technology systems providing new incentives to non-public organizations to assume control of those decisions which are directly related to their interest while leaving to public organizations the servicing of those sectors not fully incorporated to the modernization process. The main consequence is the progressive institutional fragmentation and the increasing dependence on market mechanisms for the orientation of technological change.

Summary and conclusions

Modernization implies a progressive modification of the institutional framework in which technical innovation takes place. Major modifications have resulted in the appearance of certain private and semi-public institutions. Within this context, agricultural research systems evolved from the initial stages where public efforts represents the bulk of the activities, constituting *de facto* monopolies in the supply of new technological knowledge, toward a multiorganizational structure where public organizations are now only one component of the system.

This line of evolution is evident throughout the Latin American region and has implied, in its later stages, a progressive deterioration of

[24] For an analysis of the Colombian experience in this respect, see J. Ardila and D. Londono, 'La Asignación de Recursos para la Investigación en Colombia', in *Asignación de Prioridades y Recursos a la Investigación Agropecuaria en Colombia*, Documento PROTAAL No 13, Colombia, Instituto Interamericano de Ciencias Agrícolas, 1978, (Serie Informes de Conferencias, Cursos y Reuniones No 153).

[25] For more detailed analysis of this and the Agrarian University of La Molina in Peru and INIA in Chile, see J. Ardila, E. Trigo, and M. Piñeiro, *op cit*, Ref 11.

[26] The case of ICA in Colombia is again a clear example of this type of conflict as the reorganization implied, in practice, a full concentration in the rural producer sectors; meanwhile the organization's ruling bodies structure remained with majority representation from the traditional commercial sectors (rice producer, cotton producers, coffee growers, etc.) See M. Piñeiro, *et al*, *op cit*, Ref 22, Chap 6.

the public components of the system. That is, the national research institutes created and developed during the 1950s and the 1960s and which represent the basic national capability for research and technology development. The modification of the system into a multiorganizational scheme appears almost as an inevitable consequence of the modernization process and the basic nature of market economies prevalent in Latin American countries. As conditions change and investments in technology generation become profitable, private enterprise will demand, and obtain, its share in these activities.

Public sector institutions will face continuous competition and, if subject totally to market behavioural rules, will probably be reduced to those aspects of the technology generation process with the lowest level of private return.

What has been described in relation to the Latin American national research institutes represents, perhaps, only one stage in the modernization process. However, given the characteristics of the agricultural sector in the region, the effects of this process raise a number of questions of utmost importance.

The Latin American agricultural sector is characterized, in general, 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 the more modern, 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 ecology, they seldom represent profitable alternatives for the private sector. Moreover, they do not have the basic structural conditions necessary to facilitate producer organization development.

A second aspect to be stressed is the diminishing role of the public sector in determining the nature and direction of technical change. 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 including the needs of the producers for technological inputs.

This discussion points to the fact that in dependent market economies the process of modernization and the resulting institutional changes have implied the progressive independence of technical change from organized social control other than market mechanisms.

In this regard, there are two basic questions. First, which mechanisms should be created to permit the continuous development of public sector organizations direct to servicing the non-modern segments of the agricultural sector: and, to undertake scientific and technological knowledge creation functions as needed for an effective technology generation process? Second, which are the institutional mechanisms that could allow for an effective use of international technical know-how at the same time as maintaining a reasonable degree of social control of the innovative process?

Both questions are, in the end, addressed to the discussion of the policies through which the countries of the less developed world can accelerate the generation, transfer and adoption of new technologies while controlling their undesirable effects, given the fundamental socioeconomic characteristics of each country.

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