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THE CHANGING INSTITUTIONAL NATURE OF TECHNOLOGY DIFFUSION IN LATIN AMERICA: POLICY IMPLICATIONS

M.E. Piñeiro
E.J. Trigo

I. INTRODUCTION

The countries of the Pacific Basin have gradually developed closer economic and political ties. This, together with the considerable differences in factor endowment and economic structure, provides excellent opportunities for economic and institutional cooperation.

Some of these countries, like the U.S.A., Canada and Australia, are important agricultural producers and exporters and serve as major centers for the generation and diffusion of agricultural technology to the other countries in the Basin and to the rest of the world.

Although food supply no longer seems to be the main problem in the Basin, agricultural technology continues to be a major policy issue. It has a broad effect on production, in international trade and on the very nature of society.

During past decades, technology has been visualized mainly as a policy issue related to the development and effective operation of national research institutions. The problem, however, has much wider implications, especially in view of the increasing importance of international technology transfer and the vital role of the private sector in this process.

This picture is of fundamental importance in the analysis of possible avenues of collaboration among the countries of the region. It has profund policy implications in regards to the nature of the technological process and the role of the public sector.

In line with our mandate for the preparation of this paper, we will discuss some of these issues from a Latin American perspective and attempt to draw some general policy implications.

The paper will focus on two main topics. In the first place, we will draw attention to the importance of the international and national efforts that have been made in the last few decades for the creation and development of National Research Institutes.

In retrospect, we find that relatively little effort has been made to understand the implications of the international nature of the innovative process, or to the role of what Edquist and Edqvist have called the social carriers of technology. Although extension programs have received attention as the chief mechanisms of technology dissemination inside national borders, the role of the private sector and of other informal mechanisms of technological diffusion have been for the most ignored.

With the advantage of hindsight, we would like to hypothesize the presence and nature of social carriers of technology as an extremely important element in the process of agricultural modernization in the developing world. We believe that this will be even more true in the future.

The second main topic is the recent history of agricultural technological change in Latin America. We have defined three main historical phases, each with a different prevailing institutional mechanism by which the productive structure had access to technical innovations, the majority of which had originated in the developed world.

The first phase extended through the Second World War. During this period, technology was disseminated through three main mechanisms: immigrant laborers, through the initiative and efforts of large productive units and the immigration of university scientists.

The second phase lasted until the mid - 70's and was a period of strong participation by the public sector through the National Research Institutes. Diffusion mechanisms were formalized, and autonomous research became the main policy objective.

Finally, in the third phase the private sector has become increasingly predominant. This is particularly true for the transnational firms that manufacture the inputs and capital goods implied by technological innovations.

The paper will describe and analyze these three phases, identifying in each of them the principal social carriers of technology, the social an economic forces that brought them into existence and the consequences of their work. Above all, the analysis will stress the second phase and the National Research Institutes.

Two different perspectives will be employed. In the first place, we will try to place the National Research Institutes in an appropriate historical perspective, highlighting their relationships with the institutional setting that preceded them and with the institutional developments that were set in motion, in part by their very existence. In the second place, we will briefly trace their research contributions and their real impact on agricultural development. In doing so, we will suggest that their true contribution was primarily their role in diffusing international technology and in developing human capital, rather than any direct contribution to building new knowledge.

On the basis of these findings, we will conclude that the whole process of technical change in the developing world is increasingly determined by the developments that take place in the industrialized world and by the

existence of institutional mechanisms that facilitate the emergence and operation of appropriate social carriers of international technology. We will further suggest that, under market conditions, social forces underlying development make this emergence possible and, indirectly, will bring about drastic changes in the nature of public sector institutions.

Finally, on the basis of the preceding arguments, we will highlight some of the policy issues that seem to have the highest priority in the years ahead. Although they are analyzed from a Latin American perspective, we feel that they have a wider relevance.

We would like to state from the beginning that most of the paper is highly tentative in nature. It is intended to call attention to the broad social and institutional phenomena related to the process of agricultural modernization as observed in Latin America during the post-war period.

The paper is organized in six sections, including this introduction. The second section briefly describes the early phases of technological history in Latin America. The third section gives a description and analysis of the second historical phase. It describes the development of National Research Institutes and interprets the social forces that conditioned their impact on agricultural production. The fourth section describes the main elements of the third phase which is the emergence of private sector institutions as social carriers of technology and the implications of the process. The fifth section provides a tentative interpretation of the social and economic forces that led to the creation of the research institutes and those that have eroded their original position and mandate. Finally, the sixth and last section analyzes some of the policy implications of the study.

II. PHASE ONE: THE PIONEER'S

The first phase of the technological history of Latin America is characterized by unstructured institutional mechanisms for technological diffusion. Most of the countries had little or no public research until about 1930. Even then, only minor efforts were made by the Ministeries of Agriculture of the larger and richer countries.

Three main sources of technological innovation were important during the early part of the century. First were the European immigrants who settled in the fertile and abundant farm lands of Latin America. Important examples of these immigration processes and their technological impact are reflected in grain production in Argentina and Uruguay. Immigrants introduced technical know-how and specific varieties of wheat and other grains being produced at that time in Europe, especially Italy. This defined the initial type of agriculture in the countries.

A second important form of technological diffusion took place through the special efforts and dedication of farmers and ranchers who travelled to Europe and brought back certain technological innovations they considered useful for the special production conditions in Latin America. This process was particularly important for cattle and sheep breeding in the Southern Cone countries, which became international centers of purebred stock of British origin.

The third mechanism by which technology was spread to the countries of the region was more structured and very similar to the mechanisms by which industrial technology is diffused at the present time: the activities of large and usually trasnational firms that had developed large plantations

for the production of mostly tropical crops. These firms had foreing managers who brought specific technological experience and developed mechanisms by which technological innovations, developed elsewhere and particularly in other subsidiaries of the firm, were diffused.

Concurrently,with these developments, two types of efforts took place in the public sector. The first was the development of agricultural universities which included certain research activities, mainly in Botany, Agronomy and Soils. These universities, to a great extent, grew on through the special talents of a few outstanding academicians hired mainly from Europe[1/].

In addition to these developments, a number of experimental stations were established. The most important were: today's Estanzuela in Uruguay; the Pergamino Experimental Station established in Argentina in 1914; the National Agricultural Society established in Chile in 1925; the Palmira, Medellin and Bogota Experimental Farms founded in Colombia in 1915; the Cañete (1924) and La Molina (1927) Experimental Stations in Peru; and the Central Agricultural Experimental Station established in Ecuador in 1941.

During this first phase of activity, and particularly in the case of the Experimental Stations, efforts were geared primarily to overcoming crises in certain crops. Examples are: the Cañete Experimental Station founded in Peru in 1924 to study the breakdown of genetic potential in Tanguis cotton; and the Palmira Experimental Farm consolidated in Colombia in the face of outbreaks of mosaic in sugar cane plantations of the Cauca Valley.

1/ For a discussion of this subject, see Marzocca, 1967.

The process of technological diffusion in these relatively weak and unstructured mechanisms was slow and very fragmentary. It concentrated on crops and production conditions most closely resembling those in other parts of the world. Furthermore, little or no adaptive research was done and therefore, only those technologies exactly fitted to productive needs could be profitably adopted.

III. PHASE TWO: PUBLIC SECTOR INSTITUTIONAL DEVELOPMENT

A. The National Research Institutes

In the mid - 1950's, the post-war reorganization of the international economy had important effects on economies and politics in Latin America. One fundamental outcome was a new awareness of the needs for agricultural development and the importance of technological institutions in this process.

A direct result of this new awareness was the creation of autonomous and relatively well funded research institutes in a number of countries.

Thus, with some variations from one organization to another, but always within the same general framework, INTA was created in Argentina in 1957, INIAP in Ecuador in 1959, INIA in Mexico in 1961, ICA in Colombia in 1962, and INIA in Chile in 1964. The trend toward decentralization was not limited to the technological institutions; it also affected other service areas such as marketing, credit, etc., all under the aegis of sectoral planning offices responsible for coordinating overall sectoral policy.

In the seventies, EMBRAPA was created in Brazil, FONAIAP in Venezuela, IBTA in Bolivia, ICTA in Guatemala, INTA in Nicaragua and INIA in Peru. During this period, Venezuela and Peru departed significantly from the general model. In the former, the private sector participated intensely through foundations like FUSAGRI. In Peru innovation emerged from the active participation of the University (the La Molina Agrarian University).

From the organizational standpoint, the Research Institutes, which became the keystones of the systems in 1960, were decentralized, autonomous, and covered a broad range of products, regions and farmers. Functionally, they integrated research, especially applied research, with transfer activities, including in some cases, post-graduate education (INTA and ICA).

Slight differences in the integration of functions appear in Ecuador and in Mexico. In Ecuador's INIAP, technology transfer is not a formal function of the Institution, while Mexico's INIA, conducts no livestock research.

In most cases, the Institutes were administratively organized to include National Research Centers by subject area or product, responsible for developing basic research; the experimental stations and extension agencies performed applied and adaptive research and transferred new technology. The purpose of this structure was to achieve institutional integration of the different stages of the technology generation and transfer process, and to tie the process directly to the production problems of the different regions and types of farmers.

From the operational standpoint, programs by discipline and product were superimposed on this decentralized structure. They provided a basis for developing activity programming, selecting priority actions, allocating resources and coordinating national programs.

During the first decade or so, these institutes received substantial and increasing funds, which allowed them to develop infrastructure and initiate ambitious human resources programs. Table 1 shows the funding received by these institutions and the regional totals. As can be seen, in most cases, funding grew until the middle of the 1970's and then stabilized.

The development of training programs was based primarily on technical assistance programs, although in a few countries autonomous programs were initiated with close participation by the National Research Institutes. Table 2 shows the number of matriculating graduate students in three

: 1: Funding for Agricultural Research in Latin America and the Caribbean, 1960-1980 (selected years). (Values given in 1975 United States dollars, at the national exchange rate)*.

egional[1]	1960	1965	1970	1974	1980
ern Zone (except zil)	31 446[2]	31 298	32 594[3]	44 702[4]	42 559[5]
l	8 280[6]	15 533[7]	24 178[8]	32 879[9]	116 797
n Zone	15 631[10]	20 003[11]	43 056[12]	57 393[13]	60 541[14]
n and Central ica (except co)	4 412[15]	4 967[16]	4 904[17]	5 961[18]	10 215
	4 666[19]	5 218	9 723	14 637[20]	48 357[21]
ean (except nican Rep.)	1 530[22]	1 530[23]	3 280[24]	2 940[25]	2 128[26]
can Republic	441[27]	496[27]	490[27]	2 278[28]	1 642
Latin America the Caribbean	66 406	79 045	118 225	160 790	282 239

liminary figures, still subject to adjustment

= Trigo and Piñeiro, 1981 (Doc. No. 77).

he Southern Zone includes Argentina, Uruguay, Paraguay and Chile; the Andean Zone ncludes Bolivia, Peru, Ecuador, Colombia and Venezuela; Central America includes osta Rica, Nicaragua, Honduras, El Salvador and Guatemala; the Caribbean includes uyana, Suriname, Jamaica, Haiti, Barbados, Grenada and Trinidad & Tobago.
he information for Chile is for 1961.
he information for Paraguay is for 1971.
he information for Chile and Uruguay is for 1973; the information for Paraguay is or 1972.
he information for Argentina is for 1979.
he information is for 1962.
stimated from figures by Boyce and Evenson.
ie information is for 1972.
ie information is for 1973.
ie information for Bolivia, Venezuela and Peru is for 1962; for Ecuador, 1965.
ie information for Bolivia is for 1962.
ie information for Bolivia is for 1972 and for Venezuela, 1969.
ie information for Bolivia and Ecuador is for 1973; for Venezuela and Peru, 1976.
ie information for Colombia is for 1979.

TABLE N°2: INTA, ICA AND THE LA MOLINA AGRARIAN UNIVERSITY: PERSONNEL ENTERING POST-GRADUATE STUDIES TOTAL AND IN NATIONAL PROGRAMS (1965 - 1978)

Year	INTA		ICA		LA MOLINA	
	Began Studies	National Program	Began Studies	National Program	Began Studies	National Program
1965	15	2	11	-	15	2
1966	22	3	22	-	13	2
1967	34	-	24	8	27	1
1968	28	10	35	7	24	6
1969	23	2	40	8	16	2
1970	21	5	51	15	20	4
1971	39	21	37	8	10	3
1972	24	8	110	59	10	1
1973	24	16	96	52	11	5
1974	4	-	57	40	13	5
1975	1	-	53	51	7	1
1976	2	-	28	23	6	2
1977	1	-	7	-	1	-
1978	-	-	4	3	-	-

Source: Trigo, Piñeiro and Ardila , 1980.

countries: Argentina, Colombia and Peru. Table 3 shows the total number of personnel with graduate training in the main agricultural research institutions of these three countries. Both tables suggest the considerable effort made in this field.

Almost simultaneously with the development of national research systems, international interest began to focus on the "international centers"[1/]. The rationale for this idea grew from the urgent need to develop technological know-how in basic food crops; given their wide applicability, the findings 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 full process of discovery could be performed adequately. Scientific knowledge would be expanded by academic institutions in the developed world, and technological know-how for basic food crops would be generated by the system of international centers. The National Institutes would be responsible for generating technical information on the remaining products and for developing technological innovations, adaptating them to each ecological niche and, in most cases, diffusing them into the production system through the use of extension services which, in this case, were applicable to all agricultural products.

1/ Three of the thirteen International Centers funded through the CGIAR system are located in Latin America: International Center for Tropical Agriculture (CIAT); International Center for Corner and Wheat Breeding (CIMMYT); International Potatoe Center (CIP).

TABLE N°3: INTA, ICA AND THE AGRARIAN UNIVERSITY OF LA MOLINA: TOTAL STAFF WITH POST-GRADUATE TRAINING (MS OR PH.D) 1965 -1978

YEAR	INTA	ICA	LA MOLINA
1965	56	47	49
1966	70	60	68
1967	87	90	70
1968	105	100	77
1969	120	107	90
1970	133	123	104
1971	141	142	123
1972	169	163	124
1973	193	192	126
1974	209	256	128
1975	221	311	127
1976	197	336	120
1977	195	371	117
1978	189	382	102

Source: Trigo, Piñeiro and Ardila, 1980.

The comprehensiveness of the system, and the successful experiences of most countries in the developed world in previous decades, encouraged an optimistic outlook regarding food production and rural development in Latin America. Now after three decades it is quite clear that the institutional system as developed has had a considerable impact on food production in the continent. However, it is also quite evident that the degree of success has been uneven for different crops in the various countries and that few of the success stories have touched small scale producers. The reasons for this characteristics of the process are analyzed in the following section.

B. Social Articulation and Technical Change

The establishment of the Research Institutes ushered in a strong process of technological innovation in Latin America. The Institutes represented a new or renewed effort by the public sector to generate and transfer technology, and they mobilized public opinion concerning the need to make national efforts in this area. In addition, they played an important role by articulating national efforts with international events.

The efforts in the area of technology had a heavy impact on a number of products whose economic conditions lent themselves to the process of technology adoption. Thus, a number of products have sharply expanded their yield and production in several countries of the continent. This reflects the growing international transfer of technology and the national efforts in the area (Table 4).

Table 4. Latin America: Annual percentage yield increases of thirteen products in eighteen countries (1958 - 1978)

	Wheat	Rice	Corn	Sorghum	Soybean	Cassa.	Potatoe	Bean	Cotton[1]	Sugar[1]	Coffee[1]	Banana	Milk
Latin America	1.1	0.5	1.7	4.1	2.9	-0.3	2.8	-0.1	-	0.5	0.9	-	-
Chile	0.8	1.2	2.4	-	-	-	0.9	0.8	-	-	-	-	0.4
Colombia	2.4	5.5	0.5	0.6	2.5	3.8	1.5	2.2	2.3	1.7	1.7	0.9[2]	-1.2
Ecuador	1.6	2.8	1.7	-78.8[3]	3.2	0.1	2.7	-0.6	10.0	-2.0	1.4	-0.1[2]	7.0
Paraguay	1.1	-1.2	0.3	1.1	-0.2	0.0	3.0	-0.9	5.0	-0.1	-4.9	2.2[2]	-6.2
Perú	-0.6	0.4	1.8	3.9	-1.6	-1.2	1.5	-1.4	2.6	1.1	0.1	-	5.3
Uruguay	1.3	1.5	4.3	15.3	6.2	-	1.3	-1.6	-5.0	1.8	-	-	9.2
Venezuela	-3.8	5.1	0.4	-0.1	-	0.2	2.6	-1.0	5.0	0.4	-1.7	-1.8[2]	5.1
Guatemala	4.1	2.6	3.2	5.0	-	-0.6	1.1	-0.2	-0.1	3.1	0.8	-3.5[4]	-1.8
Honduras	3.2	-1.4	2.6	0.6	-	-3.0	11.2	1.0	2.0	2.1	0.0	1.2[4]	1.9
México	5.2	2.1	2.4	3.1	0.6	-	5.1	2.5	4.7	1.2	3.7	1.6[4]	-6.0
Argentina	1.1	0.3	2.8	4.9	3.8	-1.1	3.4	-0.7	2.9	-0.6	-	4.2[4]	10.8
Bolivia	1.1	0.6	0.6	-	-3.9	-1.1	4.3	7.6	7.3	1.3	0.0	5.6[4]	2.0
Brasil	2.6	-0.4	0.9	3.4	2.0	-0.5	3.0	-1.6	7.2	1.2	-3.2	-1.3[4]	4.6
Costa Rica	-	4.6	3.0	1.5	-	3.3	1.5	3.0	-7.6	3.5	3.1	6.0[2]	1.2
Dom. Republic	-	2.5	3.0	-1.4	-	0.3	9.9	-1.4	28.7	1.7	-1.4	-3.9[2]	5.7
El Salvador	-	3.5	4.0	1.7	-	2.5	9.4	2.0	-1.7	2.0	-1.4	1.9[2]	3.2
Nicaragua	-	4.6	0.3	1.1	-	6.6	0.2	1.7	1.5	2.2	9.7	-8.2[2]	-9.9
Panama	-	2.7	0.3	-	-	-1.2	5.1	-0.5	-	3.3	0.8	-	1.4

1/ 1971-1978 2/ From 1961-1963 to 1973 3/ Only two years 4/ Until 1973

SOURCE: Prepared by authors on the basis of FAO's figures.

However, a detailed study based on seven case studies suggests that technical change was present only under some very specific economic and socio-political conditions that made possible the articulation of research and technological diffusion activities with an economic policy that made technical change profitable to specific and politically powerful social groups 1/.

The results of these studies indicate that the existence of available technology was a necessary but not sufficient condition for the existence of relevant processes of agricultural modernization.

Table 5 gives the rates of annual production increases and the per hectare yields of the products studied, by comparison with results: at the world level; on the four continents; and for the Latin American country showing the highest overall growth rate. The figures indicate that for the eight products studied, yields at the world level, and more particularly in given Latin American countries, made significant progress. This suggests that technology for increasing land productivity was internationally available. In the cases under study in Latin America, only rice production in Colombia and corn production in Argentina showed increases that approached those of countries with the highest yields.

In general, the empirical findings indicate that two principal types of social phenomena are connected with the processes of technical

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1/ The studies were on sugar and rice production in Colombia; potatoes in Peru; milk in Ecuador, corn in Argentina; livestock in Uruguay; and a multiple cropping in Northeast Brazil. In addition a study on tomatoe production in California was developed for social comparative purposes (Piñeiro et al, 1981; Barsky and Cosse, 1980; Sábato, 1980; Barbato, 1980; Alvez and Fiorentino, 1981; de Janvry et al, 1981). These case studies are presented as Chapters 4, 5, 6, 7, 8 and 9 in Piñeiro and Trigo (ed) 1982.

REASE RATES AND YIELDS FOR PRODUCTS UNDER STUDY, 1958-1978

AR	BEEF	MILK	CORN		POTATO		TOMATO [4]		BEANS	
Yield	Prod.	Prod.	Prod.	Yield	Prod.	Yield	Prod.	Yield	Prod.	Yield
--	4.59	1.56	3.17	2.38	-0.03	1.37	4.84	1.09	--	--
-0.58	4.81	1.47	5.00	6.06	-2.25	1.00	2.87	1.91	-0.61	2.22
-1.17	2.87	-0.31	2.57	3.09	1.75	2.03	2.93	2.95	0.29	0.12
0.46	6.61	2.53	3.28	1.72	2.73	2.77	5.03	1.02	2.14	-0.15
0.56	8.38	-0.85	3.18	1.33	5.92	0.25	3.28	0.98	2.37	0.72
-1.30	12.24	-3.35	2.53	0.62	5.82	-0.11	5.05	0.68	3.24	-0.57
1.67 [1]	0.90	3.60	3.70	2.80	2.30	1.50	2.85 [5]	4.16 [5]	1.70	-1.60
1.67 [1]	0.90	--	17.60 [3]	--	--	--	4.91 [5]	2.14 [5]	1.55 [1]	-4.21
3.50 [2]	11.70	7.30	6.20	4.30	14.80	11.20	--	--	10.30	7.60

F indices

*Country studied: Rice: COLOMBIA
Sugar: COLOMBIA
Beef: URUGUAY
Milk: ECUADOR
Corn: ARGENTINA
Potato: PERU
Tomato: UNITED STATES
Beans: BRAZIL

**Zone studied: Rice: VALLE DEL MAGDALENA
Sugar: VALLE DEL CAUCA
Beef: URUGUAY
Corn: "CORAZON MAICERO" - PAMPA
Potato: VALLE DEL MANTARO
Tomato: CALIFORNIA
Bean: STATE OF PERNAMBUCO
Milk: ECUADORAN HIGHLANDS

rbooks, op. cit.

change. They are framed by the nature of the process of social articulation that caused them and by the quality of technical change that took place 1/.

In one type, represented by rice production in Colombia and corn production in Argentina since the mid-1960's, the state mediates between the interest of the industrial urban centres and the more specific interests of the farmers. In both cases, this was motivated by a crisis in the production level of the commodities under study. The state helped to reach negotiated solutions which, at least in an ex-ante evaluation, respected the overall interests of the social sectors involved.

These processes of social articulation are remarkably similar to those that occurred in the developed countries after the 1950's, and more recently in some Asian countries. The overwhelming needs to increase production, and the presence of dominant social sectors capable of implementing public policies consistent with technical change, are the cornerstones of the process.

In these two cases, technological articulation was based on: a) the introduction of a technological package based on improved or hybrid varieties developed through research carried out primarily at the international level, by organizations funded and controlled independently of the productive sectors, but for which national public agencies played an important role in diffusion; and b) the definition of an economic policy to stabilize prices and to pay high subsidies for direct investment in technology adoption or capital embodied technology. These characteristics of the

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1/ For a detailed treatment of the subject, see: Piñeiro, and Trigo (ed.), 1982.

process, in addition to the qualitative nature of technological changes and the low concentration of supply, resulted in a relatively equitable distribution of the surplus among the different social sectors.

The impact of these processes of technical change on production and yields was notable, even in comparison with international results (see table 5). Moreover, the use of labor and land was capital intensive and exerted only a minor effect on the organization of the productive process, the relations of production and other aspects of the productive structure, including the degree of concentration and vertical integration 1/.

In the second type of modernization process, illustrated by sugar production in Colombia and milk production in the Ecuadorian Highlands, social articulation was generated from inside the agricultural sector. In both cases, corporate actions enabled these sectors to negotiate with the state a series of policies that served their specific sectoral interests and enabled them to begin processes of technological innovation. However, the productive sector firmly controlled the quality of these processes by defining their form and appropriating a good part of the benefits of technical change. In every case, the public policies implemented were specifically designed to overcome particular obstacles to development in the dominant productive sectors. In addition, these sectors created organizational mechanisms which gave them a certain amount of control over the supply of technology. Qualitatively, the technical change had moderate effects on yields, while production expanded through the vigorous incorporation of new areas,

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1/ In the case of irrigated rice, however, the number of farming units exceeding 30 hectares increased from 39% to 50% between 1959 and 1970.

and important changes took place in the organization of the work. Moreover, the concentration and vertical integration of production increased.

It is important to emphasize that independently of the type of social process that originates technical change its impact was to increase capital use and to homogenize the structure of production.

C. The Role of the Public Sector in the Process of Modernization

There is no doubt that the public sector as a whole played a fundamental role in the process of modernization described above. Agricultural policy and planning was strengthened considerable, and the design and application of specific policies, such as subsidized credit, was more aggressively pursued.

The research institutions played an important role in this process. They generated public awareness of the importance of technology, by developing highly trained specialists and by working toward the domestic diffusion of technology. Their role as social carriers in transferring technology available at the international level is illustrated in the seven previously mentioned studies.

In the case of milk production in Ecuador and beef production in Uruguay, public sector institutions were primarily responsible for transferring technological packages from other parts of the world. The private sector participated through the sale of the inputs and capital equipment included in the technology package; but it was the public sector that mobilized the interest of producers and made major efforts to disseminate the required information around the country.

In the cases of rice in Colombia, corn in Argentina, and potatoes in Peru, the role of the public sector was shared with other institutions. In the case of rice, major roles were played by the private sector, CIAT and the Rice Producers Federation. CIAT was the fundamental vehicle for the transferring internationally available technology and for developing new technology particularly suited to Colombian conditions. The Federation was mainly responsible for extension activities among rice producers.

Technological diffusion for corn production in Argentina was the result of two forces: international spread of technology, and the emerging work of the public sector (INTA), developing new, more site-specific, techniques. However, with time, the role of the private sector grew in importance, particularly in relation to new varieties. Private enterprise is now the major source of improved varieties.

Finally, the case of sugar cane in Colombia is an example of a very low level of participation by public institutions. For the most part, innovations were imported directly by the sugar mills, and very little endogenous research was developed.

Thus, with the exception of the case of sugar cane, public research institutions played a major role as social carriers of technology. Their role was important both at the international level and in the domestic diffusion of technology, including the mobilization of general interest in the innovation process.

However, the role of National Research Institutes in the development of new technology effectively applied to the productive process seems

to have been less effective [1/].

IV. PHASE THREE: AGRICULTURAL MODERNIZATION AND INSTITUTIONAL CHANGES

The modernization process of the past twenty years has introduced a number of institutional changes that have substantially modified the framework in which the National Agricultural Research Systems must operate, both at home and abroad.

Two types of events have been particularly important in recent years in this context: 1) the emergence of an industry that produces technological inputs; and 2) farmer organizations.

A. The Agricultural Inputs Industry

The qualitative nature of the innovative process experienced during the last two decades has implied an 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 twenty 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,

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1/ Recent unpublished estimations for Colombia by Jorge Ardila, suggest that the contributions of the National Research Institute in the development of new varieties and hybrids was in the commercial crops quite important but latter decreased. In these crops (rice, cotton, sorghum, soybean, barley, oats, peanuts, palm oil and forages) during the early 70's more than half of new releases were developed by ICA. After 1974 this proportion fill to about one fourth.

represent major examples of private enterprises's increased participation in the supply of technology. (See table 6).

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.

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.

B. Technology Generation and Transfer by Farmer Organizations

In the late sixties, and more intensely in early 1970's,farmer organizations began to directly participate in activities related to the adaptation and diffusion of technology. Development was also made possible by the advances made in basic agricultural know-how and staff training by the National Research Institutes.

TABLE 6 NITROGEN AND PHOSPHORUS CONSUMPTION PER HECTARE OF ARABLE LAND AND LAND UNDER PERMANENT CROPS IN LATIN AMERICA, 1961/1965 to 1977/1978

Country	Nitrogen Fertilizers (kg. per ha.)		Phosphorus Fertilizers (kg. per ha.)	
	1961/1965	1977/1978	1961/1965	1977/1978
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: Trigo and Piñeiro, 1981, p. 5. (Doc, 39).

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The first institutional development was the establishment of farmer organizations for technology transfer, using the same format as the Consortia of French Agricultural Technology Experimentation (CETA). These organizations acted to replace the extension systems of the Research Institutes, and created farmer groups for the purposes of contracting private technical assistance. The first such organization appeared in Argentina in the late fifties, under the name of Regional Consortia of Agricultural Experimentation (CREA). They became more popular during the following decade, particularly in the 1970's. They have now extended to other countries, especially Chile and Uruguay.

A second institutional development is more complex and far-reaching: research and technology diffusion activities were directly undertaken by the pooled efforts of farmers producing specific crops [1/]. The cases of rice and sugar cane in Colombia are interesting illustrations of this phenomenon.

Although research and transfer activities on rice began at ICA, they were gradually taken over by the technical services of the National Federation of Rice Growers (FEDEARROZ), especially in the area of technical assistance. The presence of CIAT apparently played an important role in how this process developed and consolidated.

1/ This type of institutional organizations is not new. The Colombian National Federation of Coffee Growers, for example, has run the Chinchiná Coffee Research Station for generating and transferring technology since the thirties. It began operations in 1932 and has been operating until the present as the only center conducting coffee research in that country.

The case of sugar cane differs somewhat from that of rice. Most important among the differences was the creation of a Research Center (CENICAÑA) with ties to the public system (participation of state representatives on the Board) but with a funding and decision-making process totally independent of the state and of the trade organization which created it (ASOCAÑA).

V. THE LIFE CYCLE OF PUBLIC SECTOR INSTITUTIONS: ELEMENTS FOR AN INTERPRETATION.

A. Social Forces in the Creation of the National Research Institutions

The rationale for the creation of the National Research Institutes was that, in the absence of private research efforts, they were the most efficient institutional arrangement for conducting research. On the basis of scientific and technological findings available from developed countries, their work could result in the creation and adaptation of new technological innovations.

It is interesting to note that the founding of these descentralized institutes, with the possible exceptions of Brazil and Ecuador, followed a sequence consistent with the degree of industrial development achieved.

Therefore, it is reasonable to hypothesize that the social forces necessary for this initiative to take place were present only after industrial development had ocurred. This means that the social structure had progressed to the point where urban sectors interested in forcing food production increases, had significant influence over government decisions to invest

in agricultural research. Initially, these investments were:

- relatively high in cost, due to the lack of trained personnel and the absence of an adequate research infrastructure;
- high in risk, due to the lack of experience, absence of markets of adequate size, etc.;
- difficult to recover, because it was not certain that the private sector could appropriate research benefits given that much of the new know-how in these cases concerned agronomic practices and simple technology that did not require capital inputs.

Under these conditions, technology had the characteristics of a simple public good; consequently, the rational concern of the dominant socio-economic groups was that society should assume the research costs.

In spite of these close associations between national social processes and the creation of the Research Institutes it must be noted that they appeared simultaneously in many different countries under highly divergent socioeconomic and political conditions. This suggests that the process which was underway transcended the framework of specific social processes in each country, acquiring a continent-wide dimension 1/.

In general, these processes appear to be related to the heavy influence of ECLA and its work to make the economies more dynamic by transforming them through public sector action. Another important influence was the international environment that emerged after the Punta del Este meeting, which gave rise to numerous international assistance programs for implementing new institutional models.

1/ For a detailed description of the establishment and special characteristics of the National Institutes, see: Piñeiro and Trigo (eds) 1982, Chap. 10.

The following questions about this process come to mind: Why did technology become an important social issue only as recently as the sixties? What was the origin of the institutional models adopted? How can the similarity of all the new agencies be explained? Why did the particular conditions of each country appear to have so little real influence over the organizational format of the institutions?

A possible answer to the first question can be found by analyzing the public policies and institutions for technology. Such an analysis suggests that until the sixties, conflicts over the organization of research were over-shadowed by concern for public policies of more immediate significance, that threatened the very existence of certain economic sectors (agrarian reform) or that had a clear, unequivocal economic impact (prices). At the same time, it was only recently that agricultural production stagnated, becoming a clear-cut constraint on development. Only then did it become essential to modernize agricultural production ,(Piñeiro and Trigo,(ed.)1982,Chap.10).

The questions about the origin and similarity of institutional models bring into focus the special characteristics of the relationships between technological policies and the social context. In the case of economic policy tools such as prices and credit, the effects are relatively specific for each agricultural commodity. As a result, the negotiation process was limited to those social sectors directly related to the product in question, concentrating on a small number of concrete decisions. By contrast, decisions concerning the founding, organization and budget of

technological organizations include by their very nature, the need to define comprehensive strategies for agricultural development. Thus the discussion and negotiation of state decisions assumes a more general nature, becoming more abstract and involving a much broader range of social sectors. All these factors not only delay and inhibit policies from reflecting the interests of the different sectors involved, but also complicate the mediation process between state and sector and the emergence of negotiated solutions.

Because of these factors, the state bureaucratic apparatus was able to make technological decisions with considerable greater relative autonomy than it enjoyed in other fields. This greater relative autonomy, and the classic international dissemination of ideas in the area of science and technology, made possible the adoption of institutional models developed in other countries. It also determined the selection of research priorities themselves.

In some cases, this resulted in institutional models and research priorities which had not been filtered through those social sectors that understood the concrete conditions under which production takes place. This led to inconsistencies between the models and priorities and the actual economic and political situation in each context 1/.

1/ The increasingly international nature of an organizational ideology, and the social permeability of public policy, are reflected in the similarity among institutions founded after the fifties.

B. Institutional Obsolescense as a Consequence of Changing Economic Conditions

Public sector research institutes evolved from the perception that technology was essentially a public good. Recent evidence, however, suggests that in developing market economies, this concept needs to be substantially reformulated. As indicated above, private research and extension activities have gained considerable importance during the past decade. This fact, together with the growing importance of transnational corporations and international organizations, has modified the types of technology being produced, the nature of research in public domain, and the role of public institution as social carriers of technology.

In market economies, private organizations and activities move in the area of technology development when possibilities exist for private appropriation of technology-generated surpluses. These possibilities, and the consequent development of different types of private organizations, stem from a number of interrelated and mutually reinforcing processes.

The determining factor for the development of private research and extension activities, such as those performed by the fertilizer and pesticides industry, is the existence and size of markets for technological inputs. It is also essential that existing institutional instruments enable the private sector to protect its investments in technology generation, and to internalize the possible benefits derived from technological change. Both these factors come about through agricultural modernization, making it increasingly attractive for the private sector to participate in technology generation and transfer activities.

As forward and backward linkages increase, agricultural production becomes more and more dependent on purchased inputs, thus increasing the market for technological goods. This process is generally accompanied by the public development of basic infrastructure, fostering the market integration of agricultural production. It also activates the potential demand for modern inputs, as farms become increasingly accessible to industrial sales efforts of new items. At the same time, the development of patent laws (royalties regulation, etc.) leads to the private appropriation of the benefits of technical change by the producers of inputs[1/].

These market developments, especially those affecting market conditions for embodied technologies, have been accompanied by institutional developments that also affect more general farming technologies. Farming practices are frequently mentioned as an example of technologies in the public domain, inasmuchas they cannot be protected by patent law and can be easily shared among farmers. This discourages private interest in their development. However, the process of agricultural modernization often implies developments that tend to alter this situation.

In the first place, it introduces the specialization of agricultural production and homogenizes technological interests, particularly for the

1/ For a discussion of this topic, see: Piñeiro and Trigo (ed), 1982, Chap. 6; or de Janvry, LeVeen and Runsten, 1981.

commercial agricultural sector. This process, especially when it goes hand in hand with regional localization, facilitates the development of producer organizations and fosters their involvement in a wide spectrum of service activities. This in turn, increases the possibility of private appropriation of the potential benefits of the development and incorporation of new farming practices and agronomic research in general. What ever was not profitable at the farm level becomes attractive if the cost can be shared on a more aggregate sectoral basis.

The possibility of private participation in research activities is also altered by modernization and institutional development. First, investment levels fall, as more basic scientific knowledge is accumulated and human resources are developed. Second, the level of risk for obtaining appropriate results also falls, as better methodologies and human resources become more generally available. Under these conditions, profit levels are higher and more certain, making investment in technology generation increasingly attractive for the private sector.

It is important to note the unevenness of increases among crops or different types of technology. Since the supply of basic information and technological know-how, including research methodologies, comes from the developed world, economic incentives are concentrated in areas of activity and specific products that, because they are of interest in the more developed countries, have been more fully advanced.

Although the demand for technology by productive units is basically determined by their economic conditions.

The qualitative nature of the process is at least partially determined by the international availability of basic know-how. (Schmookler, 1966) This availability not only makes some technologies possible and others impossible but it also differentially increases the private profitability of developing those which are possible (Rosenberg, 1976).

A final point has to do with the nature of public research institutions and their relationship with the state in market economies. National Research Institutions developed in earlier decades were one factor in the development of an overall state apparatus that was supposed to mobilize and coordinate the national productive system. This concept, which reflected the international atmosphere of the times, implied not only strong and centralized government activities, but also the capacity to plan and impose a general strategy for development.

An analysis of what has happened with public research organizations in a number of countries suggests that these assumptions are now, with the passage of time and the impact of the modernization process, less valid.

As has been already argued, the growth of commercial agriculture, and the gradual development of sectoral institutions whose specific purpose is to organize collective action, imply a growing need for negotiation and consensus with each economic group with regard to the implementation of specific public policies.

However, in the case of research institutions, this process has had very special results, Its main characteristic has been the inability or unwillingness of state bureaucracies to protect the monopoly status they historically enjoyed, as they have done in other areas more crucial to the

preservation of the system, at least in the short run. In this way, they have also lost their capacity to define and implement technological policy.

The basic argument presented above is intended to show that in market economies, there is a dialectical and mutually reinforcing relationship between two trends: the nature of agricultural modernization as observed, which is characterized by the development of the commercial sector through capital intensive inputs and the crops widely produced in the developed world; and the development of a multiorganizational institutional model for research, which removes the previous pre-eminence of public research institutions.

These complex and profound processes of institutional change raise a number of issues related to the implementation of technological policy. Some of them are discussed in the following section.

VI. REFLECTIONS ON SCIENCE AND TECHNOLOGY POLICY

A. Introduction

Scientific and technological policy for agriculture in Latin America has been dominated by two fundamental, closely interrelated concepts. The first is the role and nature of technology in the process of agrarian modernization. In accordance with the theory put forth by Shultz (1964). the lesser developed countries can overcome their technological defficiencies by adopting the technology available in more developed countries. This view does not take into consideration the possible undersirable effects that certain types of technologies might have on income distribution or development style. The second concept is the role assigned to the state in the technological process. It is assumed that, given prevailing economic conditions, the private sector has no interest in the process of generating, adapting and diffusing new technology. Consequently, the government must take the initiative and responsibility for agricultural research.

These concepts provided a useful basis for the policies on agricultural technology which were implemented in most of the countries of the region. The policies all tended to separate agriculture from the rest of the scientific and technological system and to provide for extensive participation in research by the public sector. Because the private sector was not participating in research, resource allocation within public sector organizations dictated research priorities and, indirectly, the supply of technology.

The interpretative analysis of the process of modernization and technical change in the agricultural sector, as presented here, stands in contrast to the concepts that have guided technological policies in recent years. This raises a number of questions.

The first and fundamental issue is that the technological process should be interpreted as a phenomenon endogenous to broader social processes that affect both the supply and the demand for technology. Consequently an effective technological policy can not be restricted to actions directed to manipulate the supply of technology. The analysis clearly shows that the presence of technology has been only one of many ingredients in the process of technical change, which also requires to unfold the presence of economic conditions that make the adoption of new techniques atractive. Thus, an effective technological policy must include policy tools to affect the supply and demand of new techniques.

The second point to consider is the legitimacy of the role assigned to the public sector in generating technological knowledge. The growth and development of market economies requires the private sector to increase its capabilities and interest in participating in activities related to the creation and diffusion of new technologies 1/.

In actual fact, this means that the role of the state in research must be redefined. Institutional mechanisms should be developed to ensure that the functions of the public sector will be carried out, and to

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1/ This concept involves the role of private groups as carriers of technology. For a discussion of the subject, see Edquist and Edqvist,1979.

guide and coordinate the functions of the other sectors involved. In this general context, the following operational aspects of technological policy are of considerable importance: a) is it possible or desireable to plan technological policy for market economies?; b) what is the best way to organize public sector research institutions?; c) what functions should these organizations perform?; d) what is the role of the international organizations, and what should the countries expect and demand from these organizations for improving the efficiency of the overall system?; e) in view of the undesireable consequences of the qualitative nature of technical change in the past, and the limitations that science imposes on planning efforts, is it possible to define an autonomous technological pattern that has different requirements for the use of factors and with different effects on productive structures?

While it is impossible at this time to discuss these questions in depth, we will briefly explore certain factors that emerge from the analysis.

B. Planning Technological Policy

The traditional model that became common in Latin America after the fifties was based on public sector manipulation of the technology supply as a means of influencing the modernization process. Experience in recent years has shown that market forces lead to major transformations in the operation of the technological process and, in particular, in the role that the state may play in guiding this process. Thus, the focal point of the discussion is the close relationship between the degree of planning of technical and scientific policies, and the degree of planning of the economy

for each particular society. If the planning capabilities are present, technical and scientific policy may become a tool for direct action on sectoral decisions. When the state's mechanisms for planning and controlling the economy are weak, the state is reduced to playing a subordinate role in the area of technology, and its sphere of action in scientific and technical policies is restricted.

The traditional approach has been to manipulate the technology supply. The unit adopting the innovations has been viewed as a simple receiver of a technological pattern defined by the public sector. However, experience seems to indicate that the important concern is not the type of technology that can be offered, but quite the contrary, the ability to influence and guide the demand for new technological know-how. In this sense, policy tools of price, credit, inputs, etc., condition the economic context in which the production unit makes its technological decisions and, consequently, they serve as the pivotal points in defining the technological paths to be followed by specific productions.

C. Organizing Agricultural Research

The basic orientation of the institutional model adopted in Latin America for technology generation has been to improve the diffusion of technology by adaptating innovations already available in the developed countries. The technological system in the region has thus taken shape within the boundaries of knowledge that are circumscribed by the priorities of the countries donating the technology. This knowledge is therefore adapted to the relative resource availability in the developed countries. In general, the resulting available technology has been capital intensive and has

centered on products and forms of production appropriate to the ecological niches of these countries. Hence, the processes of economic concentration, noted above, have been set into action, and the production of items from the temperate climates has prevailed over native products.

This trend has been further accentuated because the research organizations lack adequate mechanisms of integration into the productive sectors, often due to the public sector nature of the organizations. The basic philosophy under which they were created is to develop institutional mechanisms that will transfer technological know-how already existing in other parts of the world. As a result, research priorities and resource allocations have not always reflected a clear understanding of the productive problems of the region, placing excessive emphasis on possible alternatives from the stock of knowledge already available.

This picture suggests the need to review whether today's institutional models are still appropriate for the generation and transfer of agricultural technology. The issues discussed previously also underscore the fact that such a review should include both the structural features and the operational components of the models.

The question of whether or not a given institutional model is truly functional calls a number of considerations into play. These include: the overall and relative importance of the agricultural sector; the composition of the product and its concentration and regional homogeneity; target markets for the production; the prevailing type of social organization (types of enterprises, presence and type of trade unions or other organizations, etc.); the type of political organization; and the historical background of

each institution. However, most models implemented to date have tended to limitate successful experiences instead of producing original institutional designs based on the needs, requirements and limitations of each case. This is why a more in-depth understanding is needed of the basic principles in the dynamics of research organization in Latin America, so that institutional readjustments can be better adapted to the socioeconomic, political and ecological characteristics of the region.

In operational terms, a key area of concern is to improve coordination with the productive sectors and to develop the capability for making fuller use of native productive potential.

D. The Role of the Public Sector in Generating Agricultural Technology

Special importance in the new multi-organizational situation is attached to the gradual breakdown of the government's ability to guide the technological process, and the role that the government should play under present circumstances. As was noted above, when National Institutes were the only or most important sources of the technology supply, the process of resource allocation among organizations was an indirect means for the public sector to define technological policies.

A various sectors guided by market interest have increased their participation in the process of technology generation and transfer, the play of market forces has become the major force that governs how technological patterns determine commodities, priorities of clients, and types of technology. There are no policy tools to guide these private activities, and as a result, the technological variable has lost its influence as an active tool of agrarian policy. This phenomenon is particularly relevant in view of the

importance that agricultural sectors have for national development in the region. These sectors help allay the balance of payments problems, while technology plays a crucial role in solving world problems of food production.

The situation today, as described, suggests the need to redefine how and to what degree scientific and technical policies for agriculture will be implemented. If this is done, the public sector will be better able to guide the multiplicity of public and private organizations that are taking part in the process of technology generation and transfer, for the purpose of tapping the full potential of the new organizations. Two basic elements underlie specific actions: a) introducing a level at which coordination can be done between public agencies and the new institutions emerging in the private sector; this could take place within the general framework of technological policy coordination (National Science and Technology Councils), or at the sectoral level through councils or coordinating committees for agricultural science and technology; and b) establishing or adapting specific tools that will permit the government to exercise its full capability to coordinate and direct technological change. These tools include patent laws, technology imports, monitoring and auditing the financial mechanisms for research investments, etc.

In this general context, the government maintains its importance as a direct participant in agricultural research, but its functions and objectives operate in a different pattern.

The new organizations focus their attention on those types of technology which, by their very nature, allow for private appropriation of profits. Consequently, these activities cannot be expected to cover:

i. The development of functions for generating a "technological potential"; without these functions, the ability of the rest of the system to develop new technologies would quickly be exhausted;

ii. Specific activities which, due to their generic nature (methodological research, etc.) and to their low probability of bringing about immediate results, will not be assumed by the private sector;

iii. The development of certain type of technology which do not require inputs, such as cropping practices, pasture management, etc., in which the private sector has little interest due to the difficulty of private appropriation of their benefits.

Private sector institutions have a very specific coverage, associated with the products and conditions typical of commercial agriculture and particular forms of corporate organization. This means that a broad range of users neglected by the new institutional formats can be served only by public organizations.

In this new context, the participation of the public sector should be selective, giving special attention to the groups bypassed by the private sector, and based on the needs of a comprehensive technological policy. Similarly, it becomes more important to wield sector-wide mechanisms to guide the activities of the other components of the new institutional model. The institutional formats, as well as the type of mechanisms that will be used, depend on the nature and background of each particular situation.

E. The International Nature of the Technological Process

Word-wide developments also have a heavy influence on scientific and technological policy tools and on the role of the public sector in the technological process.

The importance of new technological inputs has grown steadily and international trade is responsible for providing these inputs. Therefore, the mechanisms that control the flow of international trade must be able to give adequate consideration to the implicit technological components.

The most important issue for the International Centers is the development of liaison mechanisms between the national and international levels. This will make it possible to improve the use of available resources and to define international priorities consistent with the needs of the national programs.

This topic cannot be discussed without taking into consideration the comparative advantages and functional limitations that each of the institutional components presents for the various types of research activities that must be developed.

Several authors have suggested that the research process can be oriented toward the following four types of activities [1/]: a) Basic research for the discovery of new knowledge; b) strategic research for solving specific and predetermined scientific problems; c) applied research for the creation of new technology; and d) adaptive research for adapting technology to the specific conditions of a given locale or production system.

1/ A detailed description can be found in the CGIAR, 1981.

The International Centers have a comparative advantage in applied research and, to a lesser extent, in strategic research for specific areas such as genetics. These advantages have been demonstrated by the actual outcome of research efforts, and the logical consequence is that the national agencies concentrate their efforts on adaptive research, on particular crops specified in the mandates of the Centers, and in general on products not studied by the Centers.

These international priority shifts and changes in emphasis mean that national priorities must be reoriented, and organizational structures altered.

F. The Limits of Autonomous Technology

Many studies have analyzed the effects of technical change on the factor use, income distribution and other economic variables directly related to development style. In response to the concerns generated by these studies, one school of thought suggests that the technological pattern can be guided by certain parameters determined by qualitative measurements. In its most extreme form, this school of thought finds theoretical backing in the concept of appropriate technology as proposed by Schumacher (1975).

This viewpoint suffers from two important theoretical problems related to the implied assumptions on which the hypotesis is constructed. The first problem has to do with the limitations of planning efforts for science and with the growing role of the private sector in the technological process. These issues have already been discussed. The second problem is related to

the concept of appropriate technology. The thrust of this concept is the search for a technological pattern adapted to the relative availability of factors in the lesser developed countries, which are characterized by abundat labor, scarce capital, and small production units. However, there are two important points to keep in mind. In the first place, the new technologies must also be efficient for market economies. This means that they must be capable of generating an average factor productivity equal to that of capital intensive technologies, so that the production units can remain competitive on the market. In the second place, the technologies must also be efficient for open economies so that the production will be competitive on international markets.

This problem must be analyzed in terms of the fact that the fundamental purpose of technical change is to develop more efficient productive processes for energy transformation[1/]. Therefore, any restrictions on how much capital can be used or on how to use it, serve to impose restrictions on the range of possible scientific discoveries.This argument suggests that capital intensive technologies are easier to invent than labor intensive technologies, as has been clearly demonstrated throughout the long history of technological innovation.

A related problem is the fact that the technology available to developing countries does not constitute the entire universe of theoretically possible technologies, but rather a sub-set of them, and they have been

1/ For a discussion of this subject, see Boulding , 1978.

developed in the industrialized countries in accordance with the conditions of relative factor prices. As a result, the imposition of restrictions on the type of technology can also reduce the utilization of cientific discovery.

It is worthwhile to note that, historically, the processes of technology adoption in Latin America have been associated with price and credit policies that use capital subsidies to distort relative factor prices and place them on a par with the prices available in the developed countries where technology was created. This leads Sábato [1/] to suggest the idea of perverse but inevitable technology. If production is to increase, technology must be adopted; but the types of technology available imply shifts in relative factors prices. These shifts, in turn, lead to overuse of capital and the perpetuation of structural unemployment.

1/ In discussions with the authors

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