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INTER-AMERICAN INSTITUTE FOR COOPERATION ON AGRICULTURE
OAS

TECHNOLOGICAL INNOVATIONS IN LATIN AMERICAN AGRICULTURE

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Elisabeth Sadoulet

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PROGRAM PAPERS SERIES

WHAT IS IICA?

The Inter-American Institute for Cooperation on Agriculture (IICA) is the specialized agency for agriculture of the Inter-American system. The Institute was founded on October 7, 1942 when the Council of Directors of the Pan American Union approved the creation of the Inter-American Institute for Agricultural Sciences.

IICA was founded as an institution for agricultural research and graduate training in tropical agriculture. In response to changing needs in the hemisphere, the Institute gradually evolved into an agency for technical cooperation and institutional strengthening in the field of agriculture. These changes were officially recognized through the ratification of a new Convention on December 8, 1980. The Institute's purposes under the new Convention are to encourage, promote and support cooperation among the 31 Member States, to bring about agricultural development and rural well-being.

With its broader and more flexible mandate and a new structure to facilitate direct participation by the Member States in activities of the Inter-American Board of Agriculture and the Executive Committee, the Institute now has a geographic reach that allows it t[illegible]d to needs for technical cooperation in all of its Member States.

The contributions provided by the Member States and the ties IICA maintains with its twelve observer countries and numerous international organizations provide the Institute with channels to direct its human and financial resources in support of agricultural development throughout the Americas.

The 1987-1991 Medium Term Plan, the policy document that sets IICA's priorities, stresses the reactivation of the agricultural sector as the key to economic growth. In support of this policy, the Institute is placing special emphasis on the support and promotion of actions to modernize agricultural technology and strengthen the processes of regional and subregional integration.

In order to attain these goals, the Institute is concentrating its actions on the following five programs: Agrarian Policy Analysis and Planning; Technology Generation and Transfer; Organization and Management for Rural Development; Marketing and Agroindustry; and Animal Health and Plant Protection.

These fields of action reflect the needs and priorities established by the Member States and delimit the areas in which IICA concentrates its efforts and technical capacity. They are the focus of IICA's human and financial resource allocations and shape its relationship with other international organizations.

The Member States of IICA are: Antigua and Barbuda, Argentina, Barbados, Bolivia, Brazil, Canada, Chile, Colombia, Costa Rica, Dominica, the Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, St. Lucia, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago, the United States of America, Uruguay and Venezuela.

The Observer Countries of IICA are: Austria, Belgium, Egypt, the Federal Republic of Germany, France, Israel, Italy, Japan, Korea, the Netherlands, Portugal and Spain.

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INTRODUCTION

In the past, technology has played a key role in promoting agricultural development and economic growth in Latin America and the Caribbean. Initially, it made it possible to incorporate new lands into agricultural activities. As horizontal expansion became more difficult, it found ways to increase production through productivity growth. Under the national and international conditions now confronting the economies of the region, the importance of technology, far from being diminished, has increased. In the short term, a growth in productivity will be needed to counterbalance the decline in international prices and maintain the region's competitive advantages in agricultural production. Over the longer term, the need for technological change arises from the new role of agriculture in the process of reactivating the economies of Latin America and the Caribbean.

For technology to play its role and contribute effectively to agricultural development and economic growth, action is required in terms of policy design as well as funding, organization and management of the technological innovation process. As these actions are designed and implemented, consideration must be given to the many new scientific and institutional developments that affect the operation of the region's technology generation and transfer systems.

Recent developments include advances in the fields of biotechnology, the growth and present situation of public research institutions, and the increasing importance of private sector participation in the technology generation and transfer process.

This paper discusses some of these issues within the context of the debt crisis in Latin America and its effects on the region's agricultural sectors. In analyzing the issues, the authors highlight their effects on the behavior of the region's technological systems. More important, they also point out their implications in terms of the agricultural technology policy options open to Latin American countries at this time.

This document was developed in preparation for the Ninth Inter-American Conference of Ministers of Agriculture held in Ottawa, Canada, from August 29 through September 3, 1987 and, together with the conclusion of the meeting on Technical Change in Latin American Agriculture held at IICA's Headquarters in San Jose, Costa Rica, May 6 and 7, 1987, served as the basis for the Conference Working Document "Technological Innovation for Agriculture in Latin American and the Caribbean: Problems, Opportunities and Issues."

Herewith, the Technology Generation and Transfer Program hopes to expand the discussion on technological policy issues and options and initiate an open forum of ideas which could lead to a more effective use of the full potential of science and technology for agricultural development and socioeconomic growth.

Finally, IICA wishes to express its gratitude to the Economic Development Institute of the World Bank for the financial support with which this document was produced.

Eduardo Trigo
Director, Program II
Technology Generation and Transfer

1

TECHNOLOGICAL DISCONTINUITIES: ADJUSTMENT TO THE CRISIS AND BIOTECHNOLOGY

The technology of Latin American agriculture will have to adjust to two major discontinuities in the years to come. One, in the short run, is the discontinuity in prices and in the level of government expenditures which is implied by the stabilization policies and the structural adjustments which have been brought about by the debt crisis. The other, in the longer run, is the discontinuity in scientific knowledge resulting from the revolutionary applications of biotechnology to agriculture.

Using the concepts of the theory of induced technological innovations developed by Hayami and Ruttan (1985), the adjustments implied by these two discontinuities can be presented in Figure 1. The innovation possibility frontier (IPF_1) indicates all the combinations of capital (K) and labor (L) that allow the production of one unit of agricultural output with the set of techniques that can be developed with the current research budget (B_1) and the existing state of scientific knowledge. With the factor ratios that prevailed before the debt crisis, technology 1 was that which had the factor ratio $(K/L)_1$, allowing minimum production costs.

Adjustment to the debt crisis will, in general, raise the price of capital goods relative to wages and lower public research budgets (B_2) for agriculture. The latter shifts the IPF to IPF_2 while the former changes the factor price ratio, making technology 2 optimum. That technology can be expected to imply a capital/labor ratio $(K/L)_2 < (K/L)_1$. Development of this more labor-intensive technology, corresponding to price ratios which are more distinct from those prevailing in the more developed countries (MDCs) than they were before adjustment to the crisis, is the immediate challenge for Latin American research and development. The greater the reduction in B, the more difficult and ineffective this necessary adjustment will be.

The biorevolution will, by contrast, shift the IPF to IPF_3, closer to the origin, as it makes resource use in agriculture more efficient. If Latin America fails to develop or gain access to biotechnologies which are adapted to its price and structural conditions and only relies on international transfers of technologies developed for the price conditions of the MDCs, it will lead it to technology 3. If the price conditions remain the same as in 2, this will imply substantial inefficiencies in resource use. If, by contrast, Latin America can successfully gain access to and adopt biotechnologies to its particular price and structural conditions, it will give it access to technology 4. While large-scale applications of biotechnology to agriculture are still several years in the future, the process through which this technology is generated is already in place. If Latin America wants to benefit from these technological advances, it must urgently adapt its technological policies to that purpose.

The nature of these two discontinuities, and how Latin America can face up to the challenges which they imply, are the subjects which we explore in this report. We start by reviewing in Part 2 the implications of the debt crisis for Latin American agriculture, most particularly for market prices and government expenditures. We then analyze in Part 3 the past

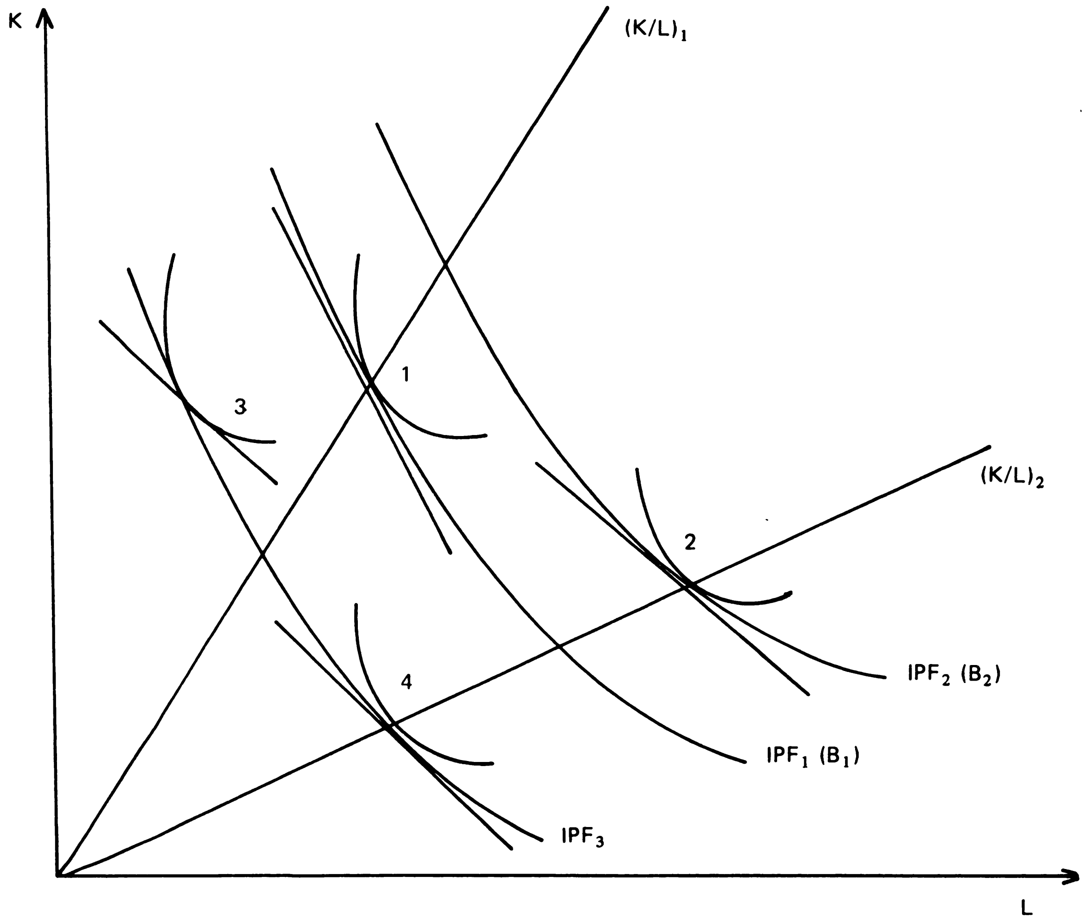


FIGURE 1. Two Discontinuities for Latin American Technology: Debt Crisis and Biorevolution. (Debt crisis: from 1 to 2; Biorevolution: from 3 to 4).

patterns of the rate and bias of technological change, contrasting the periods before and since the beginning of the debt crisis. In Part 4, we look at the organization of public sector research and how it has been affected by the crisis. Part 5 is devoted to the role of several agents in the private sector in the generation, transfer, and diffusion of technological change. This includes input suppliers on the side of backward linkages, agroindustries on the side of forward linkages, and producers' associations. Finally, in Part 6 we identify several major features of the biotechnology revolution and discuss how they create both opportunities for and threats to Latin American agriculture. We conclude in Part 7 with a number of important policy implications if Latin America is to adjust its technologies to these two major discontinuities.

This report is written with a sense of urgency created by the severity of the problem of the Latin American economic crisis and by the threats to the future of its agriculture created by the impending biorevolution in the MDCs. Jointly, these two situations imply that Latin America can least afford to invest in costly technological innovations precisely when it needs them most. The report is, however, not written as a surrender to what Albert Hirschman (1981) called "fracasomania" but, rather, to identify a feasible strategy that attributes to agriculture a key role in the reactivation of the Latin American economies and, to technological change, a key role as an important source of growth and of dynamic comparative advantages. There are three main reasons for optimism in proposing this strategy: (1) the payoffs from investment in agricultural research remain extremely high and should be even higher given the new role for agriculture in the economy and the new opportunities created by major scientific advances; (2) there exists a whole new set of institutional formulas to associate private with public efforts in research (and thus tap vast additional pools of resources) and to allow participation in and access to the technological breakthroughs already happening in the MDCs; (3) in spite of frequent misconceptions, it is in the best interest of the MDC food and feed exporters to stimulate the economies of Latin America, in particular via technological change in their agricultures. While a harmony of interests between North American and Latin American farmers requires careful management of intersectoral linkages and sustained programs of foreign aid, it can be developed and should definitely be attempted (de Janvry and Sadoulet 1987). The result is that the North American countries should indeed assist Latin America in its efforts to invest in agricultural research and become a full partner in the generation and access to biotechnological advances.

2

LATIN AMERICAN AGRICULTURE IN THE CONTEXT OF THE DEBT CRISIS

After 30 years of sustained economic growth, the Latin American economies have, since 1980, entered into a period of protracted economic crisis. While, between 1950 and 1980, the region's gross national product (GNP) increased on the average by 5.6 percent a year, this growth rate fell to 1 percent between 1981 and 1986, with negative growth rates in 1982 and 1983. On a per capita basis, gross domestic product (GDP) in 1986 was 7.6 percent below its 1980 level and at about the same level as in 1975. External debt by the end of 1986 had surpassed $380 billion, and debt service payments absorbed some 44 percent of the total export value of goods and services. The need to generate trade surpluses to service the debt put a sharp brake on imports. The nominal value of merchandise imports declined by 36 percent between 1980 and 1985. The crisis and the necessary adjustments that it implied have had extremely high social costs. Real wages, which had increased on the average by 5 percent annually between 1970 and 1980, fell by 6.5 percent annually between 1980 and 1985, and unemployment rose sharply. Per capita food intake, which had increased annually by 0.6 percent between 1960 and 1980, fell by 0.3 percent annually between 1980 and 1984. In 1984, per capita dietary energy supply was at the same level as in 1977 (United Nations-FAO 1986).

Like the rest of the economy, the agricultural sector was negatively affected by the crisis, although to a lesser extent in the short run. This relatively better performance was due largely to the fact that the lag in supply response is higher in agriculture than in the other sectors of the economy and that many investment projects financed during the period of rapid accumulation of debt were coming to fruition. The annual growth rate of agriculture, which was 3.3 percent between 1970 and 1980, fell to 1.8 percent between 1981 and 1985 (Table 1; see United Nations-FAO 1986:15). The sharpest decline occurred in the commodities with the higher income elasticities (livestock products, vegetables, and nonfood) as opposed to staple food crops.

On a per capita basis, most of the Latin American countries had positive growth rates of food production in 1971-1980 and negative growth rates in the period 1980-1985 (Table 2). Most negatively affected in the latter period were the Central American countries. The South American and Caribbean countries were able to maintain positive growth rates, although they fell sharply in South America relative to the first period.

To face up to the crisis in their economies and in order to be able to negotiate access to additional loans with international agencies, the Latin American governments had to implement drastic stabilization and adjustment policies (to reduce inflation and the deficit in the balance of current accounts). These policies include devaluation of the nominal exchange rate, freer trade, price liberalization, and reductions in government expenditures. Successful adjustment policies require the ability to reallocate resources from the nontradable to the tradable sectors (agriculture, in particular), to substitute domestic for imported goods in both production and consumption, and to increase that country's export on the world market. With relatively slow economic growth

TABLE 1

Latin American and Caribbean Countries: Production of Main Food and Agricultural Products, Annual Changes, 1971 to 1985 and 1981 to 1985

	1971-1975		1976-1980		1981-1985	
	Total	Per capita	Total	Per capita	Total	Per capita
	percent					
Total agriculture	3.2	0.7	3.3	0.9	1.8	-0.5
Food	3.6	1.0	3.0	0.6	1.8	-0.5
Nonfood	1.0	-1.5	5.6	3.1	1.4	-0.9
Crops	2.7	0.2	2.9	0.6	2.7	0.4
Cereals	1.8	-0.7	-2.4	-4.7	2.1	-0.2
Roots and tubers	-1.0	-3.4	0.2	-2.2	-0.9	-3.1
Sugar	3.2	0.7	4.0	1.7	5.6	3.2
Pulses	-1.0	-3.5	1.9	-0.5	-0.4	-2.7
Oil crops	13.3	10.5	7.6	5.1	6.8	4.4
Coffee	0.1	-2.4	10.8	8.2	0.1	-2.2
Livestock products	4.0	1.5	3.8	1.4	0.3	-2.1
Meat	4.0	1.5	3.7	1.3	0.4	-1.9
Vegetables and melons	3.6	1.1	4.6	2.2	2.3	-0.1
Fruits	3.3	0.7	2.2	-0.1	2.6	0.2

Source: United Nations – FAO (1986:15).

and rising industrial protectionism in the Organization for Economic Cooperation and Development (OECD) economies, it is unlikely that industrial exports will be able to serve as the leading sector of economic growth for most of the Latin American economies, particularly those which are not already well established in those markets. While every effort should, of course, be made to increase industrial exports within the narrow window available, it is often agriculture that will have to help generate foreign exchange savings by import substitution. This new phase of import substitution (in agriculture as opposed to industry) is not one that is made possible by protectionism and over-valued exchange rates, as in the 1940s to 1970s, but by re-equilibration of the price system and the reconquering by agriculture of the domestic market lost to imports during the periods of import substitution industrialization disequilibria and rapid debt accumulation. In this context, agriculture has a major role to play in reactivating the Latin American economies.

According to Valdes (1984), at least two-thirds of Latin American agricultural output is composed of tradable goods. Exchange rate devaluation and rising real exchange rates thus create price incentives for that part of the agricultural sector. This allows one to either increase exports and generate foreign exchange earnings or to substitute for imports and create foreign exchange savings. With the availability of foreign exchange acting as the main bottleneck to growth in the current situation, the foreign exchange contribution of agriculture can serve as a major source of economic reactivation. In addition, the incomes retained in agriculture create growth multiplier effects in the rest of the economy, both through backward linkages and through final demand

TABLE 2

Growth Rate of Per Capita Net Food Production

1971-1980 \ 1980-1985	Negative		Positive	
Negative	Ecuador	(-0.2, -3.4)	Dominican Republic	(-0.9, 0.9)
	Honduras	(-1.7, -1.4)	Peru	(-3.0, 0.5)
	Venezuela	(-0.6, -1.6)		
			All Caribbean	(-0.3, 0.4)
Positive	Bolivia	(0.2, -2.5)	Argentina	(2.2, 1.3)
	Colombia	(1.9, -0.9)	Brazil	(2.5, 0.1)
	Costa Rica	(0.3, -1.6)	Chile	(0.3, 0.9)
	El Salvador	(1.8, -2.2)	Uruguay	(0.5, 1.1)
	Guatemala	(1.3, -2.0)		
	Mexico	(0.6, -0.9)		
	Nicaragua	(0.1, -0.9)		
	Panama	(0.7, -1.0)		
	Paraguay	(0.8, -1.9)		
	All Central America	(0.6, -1.9)	All South America	(1.6, 0.3)
	All Latin America	(1.2, -0.2)		

Source: United Nations – FAO (1986).

effects. As recent studies of linkages have shown, these multipliers can be very large, with one unit of value added in agriculture easily creating one unit of value added in the nontradable sectors of the economy (Bell, Hazell, and Slade 1982). With a significant share of their resources still located in the agricultural sector, with large spaces left for import substitution in most countries, and with significant international comparative advantages in a number of products, agriculture should be looked at as a key sector for successful restructuration and reactivation of the Latin American economies. Crucial to a successful program are (1) rapid productivity growth in agriculture; (2) a neutral price and monetary policy that does not penalize agriculture, as opposed to the long tradition of import substitution industrialization policies and appreciated real exchange rates; and (3) enhanced backward, forward, and final demand linkages with agriculture for productivity growth and rising incomes in that sector, so as to create large multiplier effects on the rest of the economy (de Janvry 1987).

There are four aspects of the current international and national context in which agriculture is now placed that will have a powerful influence on its future performance. Each of them also has important implications for the role of technological change and the specifications of the desired nature of technological change.

• The first is the sharp drop in international prices for agricultural commodities since 1980; it is unlikely that prices will significantly recover for at least a decade. Between 1980 and 1986, wheat prices fell by 43 percent, rice prices by 53 percent, and the price of other cereals by 49 percent (United Nations-FAO 1986). This decline only accelerates a long-run fall in prices over the last 100 years, with the two periods of the Korean War and the World Food Crisis of 1973-1975 standing as exceptions. World Bank projections to the year 2000 show only a slight recuperation of price levels after 1987 (Mitchell 1987). Thus, the projected annual rates of growth of prices in constant dollars to the year 2000 are 1.4 percent for rice, 0.3 percent for wheat, and 2.0 percent for corn. While success in the General Agreement on Tariffs and Trade (GATT) negotiations for agriculture could raise the price level for cereals on the world market, this is not likely to happen for a number of years.

The implication for technology is that significant productivity growth will be necessary in order to make the tradable sectors of Latin American agriculture competitive in the future. This is particularly true for the countries which are exporting temperate products on the world market and which are thus competing with the European Economic Community (EEC) and the United States. As the technological treadmill pushes costs and prices down in major competing countries, similarly successful technological advances will have to be available for adoption by Latin American farmers.

• A second aspect of the current context for agriculture is that there have been major upward adjustments in the real exchange rates in every country since 1980. These adjustments have been introduced both as a forced response to the economic crisis (i.e., as part of stabilization and adjustment policies) and as a result of increasing recognition by governments in the region of the need to adopt more orthodox price policies than the ones that prevailed under the phases of import substitution industrialization and debt accumulation. These adjustments usually started with massive devaluations of the nominal exchange rates. They were followed by lesser protectionism for industry, reduction in government expenditures, the end of primary exports - or debt inflow-created Dutch diseases and the reduction of export taxes on agriculture - all of which contributed to real depreciation of money and a rise of the real exchange rate. Changes in the real exchange rate redefine the comparative advantages of Latin American agriculture. To benefit further from the opportunities created by rising real exchange rates, farmers must have the ability to reallocate resources toward the tradable sectors in which the country has comparative advantages. Since there tends to exist a considerable degree of stickiness in resource allocation in the highly dualistic structure of Latin American agriculture, significant segments of the rural population may find themselves captives of regions and types of farms with little economic opportunities in the new context. This will, in particular, be the case if peasants are principally producers of nontradable goods such as root crops, inferior cereals, and perishable goods.

The implication for agricultural technology is that it will be essential to reallocate research budgets toward the crops that have dynamic comparative advantages. Since international prices will probably continue to be unstable, it also means that the institutions involved in research will have to have a considerable degree of flexibility in reallocating resources. Since research is, by nature, a long-run enterprise with significant economies of scale and long maturation periods, the creation of flexibility in research programs will be a major challenge for the future.

• The third implication of the new context for agriculture is that stabilization and adjustment policies have not only changed the structure of relative prices between tradable and nontradable goods, but also redefined the structure of costs according to the relative importance of traded and non-traded inputs. Exchange rate devaluations have pushed upward the prices of all imported inputs. With rising unemployment levels and soaring inflation, real wage costs have been sharply reduced. The result is that those farmers using technologies with a low wage share and a high import content have been penalized by the realignment of prices, compared with farmers with the opposite cost structure. Family farms with labor-intensive technologies and farming systems and with low implicit wage costs have, consequently, often been the main beneficiaries of the price adjustments.

The implication for technological change is that cost-reducing technologies will likely have to substitute the factors that are becoming relatively cheaper (labor and land) for the factors that are becoming relatively more expensive (imported capital goods). Countries with an industrial structure able to produce modern inputs for agriculture with minimal imports of capital goods and raw materials are the ones best able to resist the rise in prices that stabilization policies imply. Redesigning technology to make lesser use of imported inputs, or to make use of inputs with a lesser import content in their domestic production, will require a major research effort. It is one that will take the Latin American nations on a technological path eventually quite different from the ones followed by the MDCs. The implication is that this appropriate technology will be less directly available on the international market for transfer and adaptation; it will have to be produced by original domestic research and development.

• The last implication of the current context for agriculture created by the economic crisis is that there has been a sharp decline in public budgets for agriculture. This includes both a decline in subsidies to the sector - principally in the form of subsidized institutional credit - and a decline in public goods expenditures. The first implies that, for the first time, agriculture will face high real interest rates equal with the other sectors of the economy. This is in marked departure from the past. In Brazil and Argentina, for instance, the credit subsidy to agriculture created by negative interest rates was often larger than the total government expenditure on irrigation, research, extension, education, health, marketing, land reform, and administration for agriculture (Elias 1985). High real interest rates imply that the new technological options for agriculture will have to reduce capital costs and be more intensive in labor and natural resources.

Declining expenditures on public goods for agriculture, such as infrastructure, research and extension, means that the growth in agricultural productivity will decline once the current technological backlog is exhausted. To avoid this, several courses of action are open:

• To increase the efficiency in the use of research budgets by the public sector in order to compensate for reduced funding. It is likely that a significant space exists here that urgently needs to be captured. This implies revising the process of decision-making in public research institutes, the structure of incentives to scientists, and the modes of interaction between public and private sector research.

• To increase the share of agricultural research in the total public sector budget. Since agricultural research is a long-term investment, taking this option in a period of falling government budgets and economic crisis will require particular wisdom and foresight by governments in power. It is, of course, well known that the returns to investment in agricultural research tend to be exceptionally high (Hayami and Ruttan 1985). In a context where productivity growth in agriculture can serve as a major source of economic reactivation, it is likely that the social value of investing in agricultural research remains extraordinarily high.

• To increase the participation of the private sector. This will require new ways of establishing cooperation between the public and private sectors, of channeling private sector monies to the public research institutions, and of internalizing the economic gains from innovation. As we will see, this requires significant institutional innovations on the definition of property rights. Not only has the role of the public sector increased in the past with the embodiment of technological advances in seeds, chemicals, and machinery, but it will take a major quantum jump with the growing role of biotechnology.

• To increase international assistance to the national research institutes and improve the linkages between international and domestic research.

3

TECHNOLOGICAL CHANGE IN LATIN AMERICAN AGRICULTURE

Contributions of Technological Change to Growth

It is by now well established that technological change is an important source of growth for the agricultural sector, becoming increasingly important as economies develop. Agricultural output growth initially based on factor deepening becomes increasingly dependent on factor productivity growth as the opportunity cost of land and labor rises. Classical studies for the United States have, for example, shown that technological change increased agricultural output by 2 percent per year in the 1940s and 1950s, and that it explained two-thirds of the rapid growth in labor productivity between 1850 and 1950 (Lave 1962). Technological change has also been important in several countries and for specific crops in Latin America.

Using a Cobb-Douglas production function, Scandizzo (1984) estimated for 20 Latin American countries the following shares of the different factors of production in sectoral output:

Factor shares	1966-1968	1978-1980	Percent change
Land	.40	.37	- 7.5
Labor	.31	.26	-16.1
Fertilizer	.08	.09	12.5
Tractors	.14	.19	35.7

As the factor shares indicate, land and labor are still the most important factors of production, but their importance is declining. Fertilizers, and especially tractors, have been assuming a growing importance in explaining total output. Combining these shares with the growth rates of factor uses gives the relative contributions of the different factors to observed growth during the period 1966-1968 to 1978-1980. Fertilizers were found to account for 43 percent of that growth, followed by tractors (28 percent), land (21 percent), and labor (8 percent). These results thus indicate that, contrary to conventional wisdom, land has not been the main source of output growth and that future gains in output seem to be largely dependent on continued adoption of landsaving fertilizers.

In a recent study of the sources of growth in nine Latin American countries, Elias (1985) showed that technological change (the residual after accounting for the role of the increase in use of traditional inputs - land, labor, and capital) explained some 34 percent of the observed growth of agricultural output between 1950 and 1980. The traditional inputs increased output at an average annual growth rate of 1.9 percent, while technological change added an average annual growth of 1.3 percent. It is in the countries with the highest rate of agricultural output (Brazil, Costa Rica, and Venezuela) that technological change made the highest contribution to total growth (Table 3). The size of the residual was itself positively associated with the rate of growth in the stock of capital, indicating that technological change is largely embodied in new capital goods.

In attempting to explain the rate of technological change, Elias found that modern inputs (fertilizers, tractors, seeds, irrigation, and draft animals) accounted for about 20 percent, while the level of government expenditures in agriculture (research, extension, administration, marketing, land reform, education, and health) explained another 20 percent. On the average, government expenditures on agriculture contributed almost 7 percent of the growth of total agricultural output. That contribution was larger when irrigation or research and extension have the largest shares in total government expenditures. Elias also found that expenditures on research and extension tended to correlate positively with the fertilizer input, suggesting that, over a span of 30 years, technological change had a landsaving bias.

We can thus conclude that technological change has been an important source of growth in Latin American agriculture, even if it has occurred very unevenly across countries. Government expenditures had a significant role in enhancing the rate of technological change. And technological change is largely embodied in the use of modern inputs, principally seeds, fertilizers, and tractors. Finally, it appears that, over the long run, the bias of technological change has been toward landsaving and yield increasing.

TABLE 3

Source of Agricultural Output Growth, 1950-1980

Country	Share of: Land	Labor	Capital	Residual	Output growth rate
	percent				percent per year
Argentina	5.2	2.4	71.4	21.0	2.10
Bolivia	16.5	26.5	61.5	-4.5	2.00
Brazil	6.7	24.9	11.8	56.6	4.50
Chile	0.0	-18.4	113.7	4.7	1.90
Colombia	7.9	5.1	45.4	41.5	3.90
Costa Rica	4.1	15.9	30.0	50.0	4.40
Mexico	8.2	6.8	36.6	48.4	3.80
Peru	5.5	35.0	18.5	41.0	2.00
Venezuela	4.9	14.7	30.8	49.6	4.90
Average share	6.6	12.5	46.6	34.3	
Average annual growth rate	0.2	0.4	1.3	1.3	3.3

Source: Elias (1985).

Diffusion of Technological Inputs and Factor Biases

We analyze here the pattern of adoption of high-yielding varieties of rice (HYVR) and wheat (HYVW) and the diffusion of machinery (tractors) and fertilizers. In Appendix 2, we give, for each country, a data set that characterizes both the diffusion of new technology and a number of price, structural, and public budget determinants of technological change.

TABLE 4

Percentage of Adoption of High-Yielding Rice Varieties

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
All Latin America	0.8	2.0	4.0	5.7	7.6	9.5	12.7	11.0	14.1	16.1	20.4	22.7	26.0	32.9	a/	
Latin America excluding Brazil	3.3	8.0	16.3	21.7	30.4	34.4	43.3	46.7	51.4	58.0	64.2	68.1	70.2			
Argentina											6.7	15.3	19.6			
Bolivia													49.3			
Brazil													11.4		10.6	
Colombia	17.6	27.9	45.4	57.0	75.4	76.9	71.2	68.9								
Costa Rica						96.2										
Cuba													87.0			
Dominican Republic				15.00			29.7						80.0			
Ecuador	19.6	12.4	19.8	50.2	82.5	74.2	61.9	69.0					63.4			
El Salvador									50.0				99.3			
Guatemala										50.0	60.0					
Guyana												57.0				
Haiti													7.4	8.0		36.0
Honduras				15.6		35.0	38.0						85.0	97.0		
Nicaragua								89.0					81.8			
Panama								51.0	37.0	37.0	69.0	87.0	90.0			
Mexico	34.1	46.3	46.1	55.1	68.2	71.1	85.00	88.0	82.0	82.0	83.0	84.0	88.0	92.0		
Paraguay							25.00						63.0			
Peru			18.2	36.5	33.4	70.1	37.6	53.6					74.3			
Suriname								92.0					92.0			
Venezuela													87.3			

a/ Blanks indicate no data available.

Source: Dalrymple (1986a).

Diffusion of HYVs

Tables 4 and 5 give data compiled from Dalrymple's (1986a, 1986b) studies of diffusion of Green Revolution technology. They show that the diffusion of HYVs has been both very rapid during the 1970s and, with the exception of Brazil, Bolivia, and Haiti, very extensive. In 1983, 78 percent of the area planted in wheat was in high-yielding dwarf varieties, and it had reached virtual saturation in Argentina, Colombia, and Guatemala. Excluding Brazil, 70 percent of the rice area of Latin America was in high-yielding varieties in 1982. More than 90 percent of the area planted in rice was in HYVs in Costa Rica, El Salvador, Honduras, Panama, Suriname, and Mexico.

It is remarkable that only Brazil, Bolivia, and Haiti are lagging in the adoption of HYVs in crops of national significance. Diffusion has been wide-spread in all the other countries in spite of substantial differences in use of fertilizers per hectare and in research budgets per hectare. Indeed, no simple explanation seems to be available to observe the different levels of adoption across countries.

Across farm sizes, diffusion remains unequal with eventually near saturation in commercial farms (wheat in Mexico) and very little adoption in peasant farms. Yet, near saturation in many countries does suggest that peasants do eventually adopt modern varieties, if later than commercial farmers. If, however, prices have fallen in the meantime due to adoption by large farmers, as was the case with rice in Colombia (Scobie and Posada 1977), small farmers

TABLE 5

Percentage of Adoption of High-Yielding Wheat Varieties

	1977	1978	1979	1980	1981	1982	1983	1984	1985
All Latin America	a/						78		
Argentina	18	29	27	37	48		90	95	
Bolivia									35
Brazil						30	43		
Chile						70	70		
Colombia							100		
Ecuador						25			
Guatemala					100	100	100	100	100
Mexico							98		
Paraguay							10	20	
Peru						10			
Uruguay						61	75	82	

a/ Blanks indicate no data available.

Source: Dalrymple (1986b).

may well have been eliminated from production of that crop before they are in a position of adopting the technological advance. This process of elimination of peasant production through differential adoption of technological change across farms and the subsequent deterioration of prices due to inelastic demand has occurred principally when HYVs are unfit for peasant farming systems, for the types of resources they control (dry-land rice in Colombia), or for the regions where they are located.

Patterns of Factor Use: Fertilizers and Tractors

Fertilizers and tractors, together with seeds, are the most important modern inputs that embody technological advances. Fertilizers are generally landsaving (yield increasing), while tractors are principally laborsaving. In recent studies of the pattern of technological change in Latin America, Piñeiro (1985) has suggested that there has been a succession of cycles of technological change where each phase was dominated by the diffusion of a particular technology: agronomic practices (1940s), machinery (1950s to mid-1960s), new seeds (mid-1960s to mid-1970s), and agrochemicals (mid-1970s to mid-1980s), expectedly followed by the diffusion of biotechnologies. Existence of such a stable pattern across countries would suggest that the main determinant of the diffusion of technological change was its international availability. While this particular sequence may indeed characterize several of the Southern Cone countries' agricultures, it is not similarly replicated in all countries, suggesting that international availability may indeed be necessary for adoption, but not sufficient. We will show that the determinants of technological change have to be found instead in three categories of variables:

- Product and factor prices (profitability and optimum bias).
- Public budgets for research and extension (availability).
- Structural characteristics of the farm sector, farm size in particular (farm specificity of technology and lobbying).

Historically, we see in Table 6 and in the graphs in Appendix 2 that there were three markedly contrasted phases in the pattern of technological change: (1) an early period between the mid-1950s and the mid-1960s where modern inputs started being introduced; (2) a period of rapid diffusion of technological change between the mid-1960s and the mid-1970s; and (3) a period of crisis and instability in the late 1970s and the beginning of the 1980s.

While data are incomplete, the pattern of adoption of fertilizers and tractors occurred differently in three groups of countries. In Bolivia, El Salvador, Honduras, and Suriname, there was rapid mechanization during the 1970s with a falling fertilizer/tractor ratio. Mechanization was abruptly stopped during the crisis of the 1980s while the adoption of fertilizers continued (except in El Salvador). The result was a rising fertilizer/tractor ratio during this last period.

In Argentina, Brazil, Chile, Peru, Uruguay, and Venezuela, the pattern of diffusion of fertilizers and machinery is exactly the opposite of that in the above group of countries during the last two periods and more like the sequence described in Piñeiro. Mechanization was progressing rapidly in Argentina and Brazil in the earlier period. This was followed, between the mid-1960s and the mid-1970s, by rapid diffusion of fertilizers and a rising fertilizer/machinery ratio. The crisis of the 1980s led to a dramatic fall in fertilizer use induced by exchange rate devaluations and rising fertilizer prices. With mechanization relatively unaffected, the fertilizer/tractor ratio fell sharply.

TABLE 6

Patterns of Factor Use

		Mid 50s to mid 60s			Mid 60s to late 70s			Late 70s, early 80s		
		F	M	F/M	F	M	F/M	F	M	F/M
					(annual growth rate in percent)					
Bolivia	71-75				11.0*	19.3	-23.5			
	75-84							6.7	0.9	5.6
El Salvador	71-78				6.9*	6.7	-3.5			
	78-84							-6.9	0.9	-7.8
Honduras	71-79				.2*	17.7	-19.1			
	79-84							7.4	0.9	5.3
Suriname	71-80				-7.6	3.8	-11.4			
	80-84							41.8	4	37.7
Argentina	56-62	-0.9	14.3	-15.3						
	62-72				14.3	3.9	10.6			
	72-82							2.1**	0.9	1.2**
Brazil	52-66	8.1	6.9	1.2						
	66-80				18.4	11.5	6.7			
	80-84							-6	24.2	-30.1
Chile	64-74				4.2	3.6	0.5			
Peru	68-78				6.9	1.6	13.1			
	78-84							-9.7	5.3	-15.2
Uruguay	71-79				-1.6	0.5	-2.1			
	79-84							-14.3	4.6	-18.9
Venezuela	61-79				17.6	6.9	8.2			
Colombia	50-78	←	←	←	13.3	6.4	6.9			
	78-84							3	0.9	2.1
Mexico	50-56	34.3	8.7	25.5						
	56-82	←	←	←	10.6	1.8	8.8	→	→	→
Canada	70-84				7.8*	0.7	6.2	→	→	→
USA	68-76				3.9	-0.9	5.1			
	76-84							-0.7	0.5	-1.2

* From 1968
** Very irregular

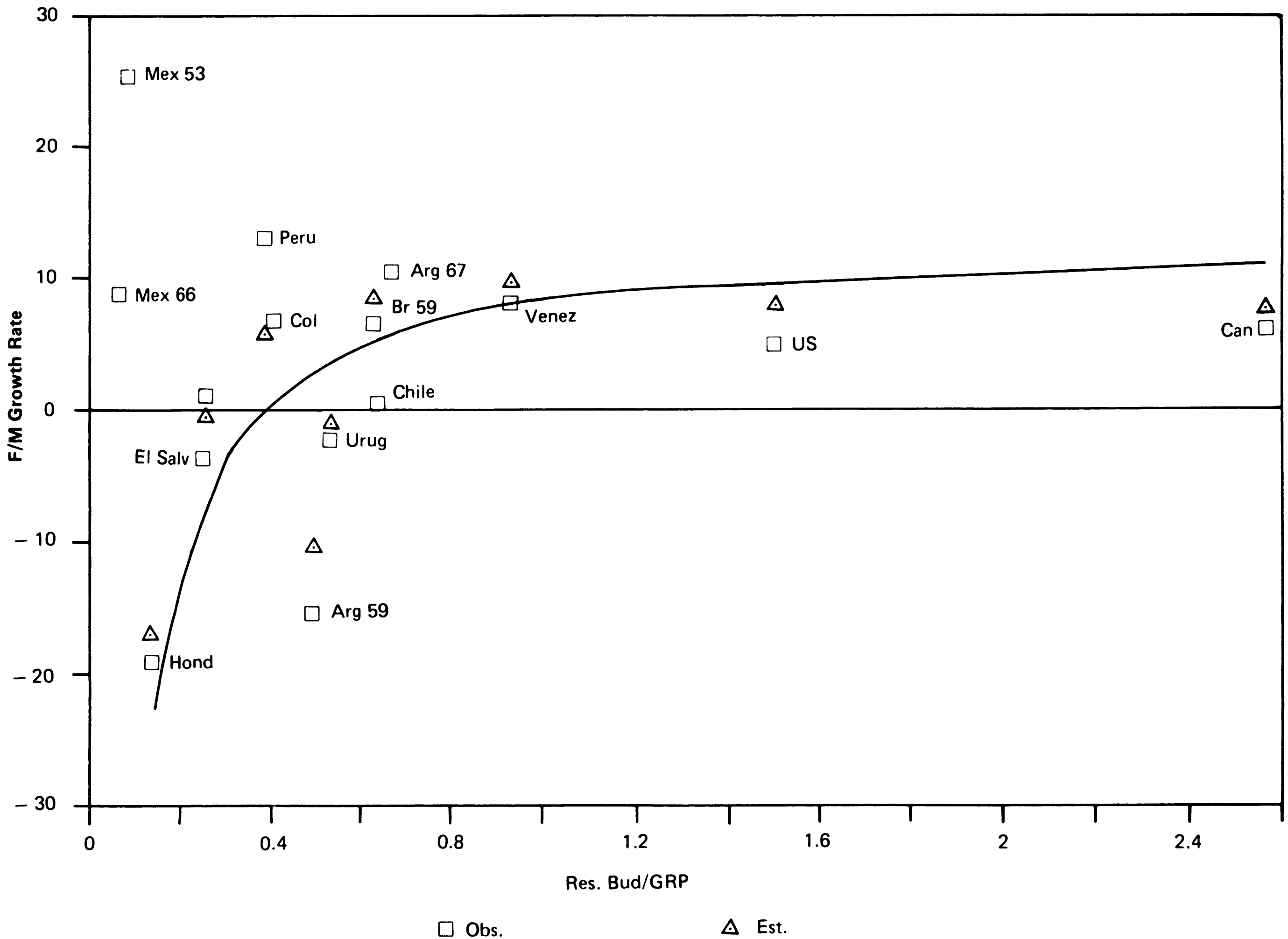
In Colombia and Mexico, as well as in Canada and the United States, the pattern of diffusion of fertilizers and tractors was fairly stable throughout the three periods. The fertilizer/tractor ratio continued rising over time, although at a declining rate during the latter period.

We thus conclude that there is no unique sequencing of technological innovations across Latin American countries and that the crisis of the 1980s has not had a unique impact on the bias of technological change. This indicates that international availability of new technologies is not a sufficient determinant of adoption. Variables such as product and factor prices, public research budgets, and the structure of agriculture need to be taken into account. This is what we do in the next section.

A Cross-National Analysis of the Factor Bias

The data in Table 7 and Figure 2 give the growth rate of F/M (the fertilizer/tractor ratio) in different periods and countries related to the research budget (B) per unit of agricultural GDP (gross rural product, GRP). They show that F/M (the growth rate of F/M) is an increasing function of B/GRP with a tendency toward strongly decreasing returns when B/GRP reaches

FIGURE 2: FACTOR BIAS



about 1 percent. The public research budget is thus biased toward landsaving technological change, and this bias stabilizes at a growth rate of F/M at about 10 percent.

Observation of the outliers in Figure 2 reveals the importance of additional variables:

TABLE 7

Determination of Factor Bias

	F/M Growth rate (percent) (1)	ResBud/GRP (percent) (2)	Av. Farm size (ha) (3)	Ag. Wage 1970 (US$) (4)	GDP/c mid-year 1970 US$ (5)
Argentina 56-62	-15.3	0.493	383.1	60.4	736
Argentina 62-72	10.6	0.665	270.2	60.4	858
Bolivia 71-75	-23.5	0.13			265
Brazil 52-66	1.2	0.259	75	23.3	347
Brazil 66-80	6.7	0.627	59.7	23.3	630
Canada 70-84	6.2	2.57	187.6	225	4 256
Chile 64-74	0.5	0.636	118.5	30	861
Colombia 50-78	6.9	0.409	26.3	25.2	287
El Salvador 71-78	-3.5	0.252	4.6	27.2	342
Honduras 71-79	-19.1	0.138	13.5	22.6	258
Mexico 50-56	25.5	0.083	123.9	48.8	407
Mexico 56-82	8.8	0.063	137.1	48.8	579
Peru 68-78	13.1	0.387	16.9	27.3	549
Suriname 71-80	-11.4		5.9		914
Uruguay 71-79	-2.1	0.531	214.1	70.9	936
USA 68-76	5.1	1.5	157.6	252	5 125
Venezuela 61-79	8.2	0.926	91.9	77.2	1 086

Source: (1) – Computed.
(2) – Bolivia and USA: Research Budget in 1971 from Boyce and Evenson.
Other countries: Research Budget per Ag. Value Added in closest year from ISNAR.
(3) – In closest year of census: FAO, 1970 World Census of Agriculture.
(4) – Latin America: de Janvry, Sadoulet and Wilcox.
Canada, USA: ILD, Yearbook of Labour Statistics.
(5) – World Bank, World Tables.

• Mexico, Peru, and Colombia all have high F/M in spite of low research budgets. All three countries host international research centers indicating that the research budgets of these centers are important complements to national research budgets. This observation was also made in a recent paper by Judd, Boyce, and Evenson (1985).

• Countries with low F/M for a given B/GRP all have large farm sizes and relatively high agricultural wages. They are Argentina, Uruguay, Chile, the United States, and Canada.

To show the importance of research budgets, farm sizes (A), and agricultural wages (w) on F/M, the following equations were estimated (omitting Mexico, which is a clear outlier) for the period before the crisis of the 1980s:

$$F/M = \underset{(3.6)}{19.7} - \underset{(4.49)}{4.95}\,\frac{1}{B/GRP} - \underset{(3.3)}{.052}\,A \qquad R^2 = .71$$

$$F/M = \underset{(3.1)}{17.7} - \underset{(4.1)}{5.27}\,\frac{1}{B/GRP} - \underset{(2.4)}{.047}\,A + \underset{(0.4)}{80.6}\,\frac{1}{w} \qquad R^2 = .72$$

$$F/M = \underset{(0.8)}{5.39} - \underset{(3.4)}{5.26}\,\frac{1}{B/GRP} + \underset{(1.7)}{320.3}\,\frac{1}{w} \qquad R^2 = .55$$

(Figures in parentheses are t ratios; number of observations = 13)

The results show the following:

• As expected from the theory of induced technological innovations, higher wages tend to bias technological change toward laborsaving innovations. Because wages and farm size are highly correlated, both variables cannot be used simultaneously. Cross-country price data are, unfortunately, not available for tractors and fertilizers.

• Larger farms are associated with a stronger laborsaving bias in technological innovations. This is due to two cumulative phenomena:

a) Transactions costs tend to raise effective labor costs and to lower effective land costs as farm size increases. This is due to labor recruitment and supervision costs that increase with the number of hired workers and also due to fixed costs in land transactions. The result is that the optimum technological bias is more laborsaving on the large farms and more landsaving on the small farms. In addition, transaction costs and privileged access to subsidized institutional credit tend to lower the effective price of financial capital as farm size increases. Since capital inputs (fertilizers and tractors) embody land- and laborsaving technological change (respectively), differential capital costs across farm sizes further reinforce an observed bias in technological change toward mechanization as farm size increases.

b) Following the logic of collective action (Olson 1965), large farmers' lobbies are more likely to be effective than small farmers' lobbies. The result is that the larger farmers' optimum technological bias, which is more landsaving, tends to dominate the allocation of public research budgets over the optimum bias of small farmers.

• The size of the public research budget affects the bias of technological change in the opposite direction than farm size and wage level; it increases the bias toward landsaving technological change. This is principally due to the fact that mechanical innovations, by being internationally transferable without adaptive research, and by being patentable, tend to originate in the private sector. Biological innovations, by contrast, require adaptive research and are not as easily patentable. They tend to depend consequently, on the existence of public research budgets. Public research budgets thus support adaptive research on new genetic materials which, in turn, enhance the demand for fertilizers. Higher public research budgets thus increase the factor bias of technological change in the direction of the small farmers' optimum bias.

Time Series Analysis of Demand for Modern Inputs and Technological Bias

Time series data on factor prices are available in the FAO Production Yearbooks, but only since 1968. Together with data on product prices prices, they can be used to estimate derived demand functions for tractors and fertilizers and for the bias of technological change

TABLE 8

Time Series Analysis of Factor Use

	Elasticities with respect to					
	m/p	f/p	w/p	f/m	f/w	R2
Fertilizer (F)						
Argentina 1976-83	2.5	-0.2				0.81
	(4.)	(.7)				
Brazil 1979-84	-0.85	0.54	-0.02			0.36
	(.5)	(.4)	(.1)			
Canada 1971-84	-1.2	1.3	0.7			0.32
	(1.3)	(1.3)	(.7)			
Mexico 1968-84	0.05	-1.13	0.68			0.96
	(.3)	(11.3)	4.3			
Uruguay 1975-84	0.07	-0.69	0.54			0.22
	(.1)	(.4)	(1.2)			
US 1968-84	1.5	-0.3	-1.8			0.38
	(2.5)	(1.0)	(2.4)			
Machinery (M)						
Argentina 1976-83	0.3	0.1				0.08
	(.6)	(.5)				
Brazil 1979-84	0.56	-0.3	-0.18			0.91
	(.4)	(.3)	(1.0)			
Canada 1971-84	-0.21	0.18	0.13			0.5
	(2.2)	(1.8)	(1.2)			
Mexico 1968-84	0.15	-0.19	-0.39			0.34
	(.7)	(1.7)	(2.3)			
Uruguay 1975-84	-0.11	0.04	-0.21			0.42
	(.5)	(.1)	(1.5)			
US 1968-84	0.14	-0.02	-0.09			0.16
	(.7)	(.2)	(.3)			
Ratio (F/M)						
Argentina 1976-83	2.2	-0.3				0.69
	(2.7)	(.9)		-0.6		0.43
				(2.1)		
Brazil 1979-84	-1.4	0.85	0.15			0.86
	(.6)	(.5)	(.5)	0.79	-0.26	0.85
				(.7)	(4)	
Canada 1971-84	-1	1.1	0.6			0.3
	(1.2)	(1.3)	(.6)	0.88	-0.55	0.08
				(1)	(.5)	
Mexico 1968-84	-0.11	-0.94	1.07			0.93
	(.4)	(6.6)	(4.7)	0.11	-1.06	0.93
				(.4)	6.6	
Uruguay 1975-84	0.18	-0.73	0.75			0.24
	(.2)	(.4)	(1.3)	-0.28	-0.72	0.24
				(.5)	(1.5)	
US 1968-84	1.4	-0.3	-1.7			0.27
	(2)	(.9)	(2)	-0.57	-0.67	0.16
				(1.4)	1.6	

t-ratios in parentheses

(F/M). Little attention has been paid in Latin America to price determinants of technological change, and conventional wisdom is that prices have been secondary in the inducement of innovations relative to forces originating in the political economy (Elliott et al. 1985).

Table 8 shows the results of double-log derived demand and factor bias equations. The expected signs are as follows:

	Log m/p	Log f/p	Log w/p	Log f/m	Log f/w
Log M	-	+	+		
Log F	+	-	?		
Log F/M	+	-	-		
Log F/M				-	-

where

p = product price
m, M = tractor price and quantity
f, F = fertilizer price and quantity

and

w = wage rate.

With the exception of a few cross-prices, all the price effects which are statistically significant are of the correct sign, indicating that price effects do indeed matter, and in the direction predicted by the theory of induced innovations. Lack of significance of many prices, however, also indicates that other forces than prices are at work. As the cross-sectional results of the previous section showed, they include structural characteristics of agriculture and the role of the state.

Cross-Sectional Analysis of the Crisis

As we saw, the crisis affected the fertilizer/tractor (F/M) ratio differently in different countries. In most countries (Argentina, Brazil, El Salvador, Peru, and Uruguay), the F/M ratio fell, indicating that the adoption of fertilizers was negatively affected by the crisis more than that of tractors. In trying to explain this by changes in relative prices of fertilizers and tractors (f/m), we see in Table 9 that this price ratio increased in all countries (not significant in Uruguay, Brazil, and Colombia). The crisis thus raised the price of fertilizers more than that of tractors, explaining part of the change in technological bias. It should be noted, however, that lack of correspondence in several changes in F/M and f/m indicates that a number of other factors were in play as well. In Bolivia, for instance, a strong increase in f/m with no significant change in F/M suggests that hyperinflation reduced the ability of the farm sector to adjust technological choices to changes in relative prices.

TABLE 9

Impact of the Crisis on Technological Bias

Country	Period	Annual percentage changes of: Fertilizer/tractor ratio	Fertilizer/tractor price ratio
		percent	
Argentina	1979-1984	-4.7 (-1.04)[a]	6.5 (2.24)
Brazil	1980-1984	-30.2 (-2.80)	1.6 (0.36)
El Salvador	1978-1981	11.2 (-.85)	6.8 (13.6)
Peru	1978-1984	-9.7	b
Uruguay	1979-1984	-18.8 (-4.09)	-0.9 (-0.47)
Bolivia	1978-1981	9.5 (0.43)	31.0 (3.69)
Colombia	1978-1984	1.4 (0.93)	2.8 (1.22)
Honduras	1979-1984	7.4	b
Suriname	1980-1984	41.8	b

a Figures in parentheses are t-ratios.
b No data available.

4

PUBLIC SECTOR RESEARCH

The key role of the public sector in agricultural research is dictated by two economic factors. One is that many aspects of research are in the nature of public goods when the economic returns from innovation cannot be appropriated privately. This is particularly the case for biological research as opposed to research on machinery and chemicals, where the returns from innovation are more easily protected by patents. If mechanical innovations are laborsaving and biological innovations are landsaving, it is, consequently, no surprise that public research budgets tend to reduce the laborsaving bias of technological change. The other reason why public sector research is important in agriculture is because the ultimate beneficiaries of technological change are often not directly involved in the process of decision-making in choosing among technological alternatives. This is the case for technological innovations that lower consumer prices (output-increasing innovations in the context of inelastic demand) or relax the foreign exchange constraint on the economy. In this case, the state acts as a surrogate for the diffused ultimate beneficiaries of technological change. As observed in the Cooperative Research Project on Agricultural Technology in Latin America (PROTAAL), it is, consequently, no surprise that successful dynamic sequences of technological change tend to occur in either one of two circumstances:

- When the conditions for effective collective action by organized producers, identified, for instance, by Olson (1965) and Hirschman (1980), hold. This is the case when groups are relatively small, homogeneous, geographically concentrated, bound by a collective ideology, and have been in existence for some time. These group characteristics minimize free riding. PROTAAL thus observed successful technological developments initiated by sugar plantations in the Cauca Valley of Colombia and milk producers in the large haciendas of Ecuador.

- When the state has sufficient leadership and foresight (often propped up by international agencies) to initiate technological programs on behalf of nonfarm interests (consumers and employers; importers). This will concern commodities of national significance either as wage goods or as sources of foreign exchange earnings (exported) or savings (import substitution). While the early innovators in agriculture can derive Schumpeterian rents, the bulk of benefits are extracted from the farm sector through the mechanisms of falling prices. Technological change in rice in Colombia is an illustration of this process (Scobie and Posada 1977). If, of course, demand is elastic because of export demand (corn in Argentina) or government price support, the benefits of this technological treadmill are not extracted from agriculture but retained there and capitalized in land values. An active state can thus also act on behalf of a disorganized agricultural sector when rising agricultural rents also create benefits in the rest of the economy - foreign exchange earnings, for instance.

Technological stagnation will, by default, tend to occur when the conditions for either of these two sequences fail to exist. This is the case when producers are numerous, heterogeneous, dispersed, and disorganized - a typical feature of peasant producers - and when the commodity in question has little national economic significance either as a wage good or as a tradable good. PROTAAL thus observed technological stagnation in potato production in Peru and in the production of food and fiber crops in northeastern Brazil.

Organization of Public Sector Research

As in the MDCs, public sector research and extension have been important in Latin America. The process of institution building has been extensively documented by Trigo and Piñeiro (1981) and Piñeiro and Trigo (1985). It was summarized by Elliott *et al.* (1985) as follows:

Starting with the post-war period, there was increased awareness in the region that science and technology could be tools for transforming society. The view was particularly prevalent within the agricultural sector. On the one hand, there were the successful experiences of the developed countries; on the other, there was the presumption that it was easy to transfer agricultural technology from one country to the other (Schultz 1964).

The focus of action was on the creation of national agricultural research institutes, responsible for mobilizing national and international resources in support of agricultural production. Some of these institutions have been in operation for more than a quarter of a century and are now entering new phases in their institutional development; at the same time, the conditions that existed when they were created have changed, partly as a consequence of the modernization process, of which they have been part (Trigo and Piñeiro 1981; Piñeiro 1985).

Initially, the problem was conceived as one of transferring technologies from developed to underdeveloped countries. To achieve this, infrastructures capable of adapting available technologies to local conditions were needed. Existing agricultural research capacities, usually located within ministries of agriculture, were not thought to be adequate for the task. Deficiencies were perceived in budgetary support, farmer participation, communications between researchers and extension personnel, and coordination between organizations generating technology and others providing support services (Samper 1977; Trigo *et al.* 1983).

The solution was to make agricultural research administratively independent of the ministries. It was believed that this would provide research managers with greater control over resources, together with the opportunity to develop management practices, of a research organization including conditions of service for personnel and disbursement procedures. Other important features of the institutes were their central funding, formal linkages with economic and sectoral planning activities, and operational decentralization through a network of experiment stations and commodity programs.

The national research institutes received significant support from donors, and particularly from Point IV of the U.S. Foreign Aid Program. This was channeled through massive institution-building projects, which included technical assistance, as well as crucial support for human and infrastructure development.

From this process emerged the National Institute of Agricultural Technology (INTA) of Argentina in 1957; the National Institute of Agricultural Research (INIAP) of Ecuador in 1959; the complex **Consejo Nacional para el Fondo Nacional de Investigaciones Agropecuarias** (CONIA-FONAIAP) in Venezuela, between 1959 and 1961; the National Institute of Agricultural Research (INIA) in Mexico in 1960; the Agricultural Research Promotional Service (SIPA) in Peru which, after successive modifications, became the National Institute of Agricultural Research Promotion (INIPA) in 1984; the Colombian Agricultural Research Institute (ICA) in 1963; and the Agricultural Research Institute (INIA) of Chile, in 1964. In the 1970s, the Bolivian Institute of Agricultural Technology (IBTA); the Institute of Science and Agricultural Technology (ICTA) in Guatemala; the Agricultural Research and Development Institute (IDIAP) of Panama; and the National Institute of Agricultural Technology (INTA) in Nicaragua were created. Since 1980, INTA has been placed under the direct control of the Ministry of Agriculture (Piñeiro and Trigo 1985).

Research Budgets and Scientists: Austerity and Decline

Research budgets increased rapidly in the period between 1960 and 1979 (Table 10). For the 15 Latin American countries for which International Service for National Agricultural Research (ISNAR) data are available, the average annual growth rate in research expenditures in real terms was 6.4 percent, with spectacular growth rates in Mexico (12.8 percent), Brazil (14.5 percent), and Ecuador (12.1 percent). Research budgets were also increasing relative to the agricultural GDP (GRP), indicating a clear consciousness on the part of Latin American governments of the importance and high rates of return derived from investing in the generation of technological change. In only two countries, Honduras and Colombia, were research budgets declining relative to earlier periods. The number of research scientists was increasing even faster, reaching 8.7 percent for Latin America as a whole. The implication, of course, is that research resources per scientist were declining, particularly in Central America. In spite of this, as Table 11 shows, government expenditures on agricultural research and extension remain a modest fraction of total government expenditures. In 1980, it averaged only 0.3 percent in the six countries for which information on both research and extension (R&E)/government expenditures on agriculture (GEA) and government expenditures on agriculture (GEA)/total government expenditures (TGE) is available; see Table 11.

This period of sustained expansion was, with a few exceptions, brought to a halt by the crisis of the 1980s. The decline was particularly marked in the Andean and Southern Cone countries, where the average annual growth rate fell to -2.7 percent. Additional data cited by Piñeiro and Trigo show that the annual rates of decline, between 1980 and 1983, in resources received by the Institute of Agricultural Technology (INTA) of Argentina, EMBRAPA of Brazil, and the Agricultural Research Institute (INIA) of Chile were, respectively, -30 percent, -9 percent, and -12 percent. This reduction in public expenditures on agricultural research came in the context of stabilization policies and a global reduction in government expenditures. Mexico and the Central American countries were, however, not affected by the crisis, at least as reflected by the 1980-1984 average level of research expenditures. Thus, either the crisis came later in these countries or they were better able to protect research budgets. In all of Latin America, not only did research expenditures continue to grow, but the number of research scientists increased even faster. The result was a sharp deterioration in resources per scientist in both the Central American and the Andean and Southern Cone countries.

TABLE 10

Annual Growth Rates in Research Budgets, Number of Man-Year Scientists, and Research Budget per GRP[a]

	Research budget (B)		Man-year scientists (R)		B/R		B/GRP	
	1962-1977	1977-1982	1962-1977	1977-1982	1962-1977	1977-1982	1962-1977	1977-1982
	percent							
Costa Rica	6.5	- .5	2.1	5.7	4.3	-5.8	1.2	2.3
El Salvador	7.4	1.6	4.3	5.0	-1.6	2.4	2.0	-3.5
Guatemala	2.0	5.7	14.3	13.2	-7.2	-6.6		
Honduras	-3.1	4.0		4.8			-5.8	2.4
Nicaragua	5.6	1.0	10.4	13.5	-4.4	-11.1	0.3	6.1
Panama	7.1	19.4	21.2	6.6	-6.9	0.7	2.9	17.8
Central America	4.3	4.7	10.5	8.1	-3.2	-4.1	0.1	5.0
Mexico	12.8	13.1	10.3	6.9	2.2	5.8	8.3	12.9
Argentina	2.8	-4.1	5.5	2.9	-2.6	-6.8	3.5	-5.8
Brazil	14.5		8.8	7.4	5.5		9.0	
Chile	6.5	-3.3	3.7	- .1	2.7	-3.2	5.6	-3.1
Colombia	- .2	-2.1	1.8	1.6	-2.0	-3.7	-4.2	2.9
Ecuador	12.1	-2.1	15.2	10.1	-2.7	-11.1	8.1	- .5
Peru	7.8	.1	6.2	5.9	1.5	-5.4	5.9	6.0
Uruguay	6.2	-5.8	8.9	-2.4	-2.4	-3.5	7.0	-7.0
Venezuela	7.9	-1.6	9.4	-2.3	-1.4	0.8	3.2	-2.9
Andean and South Cone	7.2	-2.7	7.4	2.9	- .2	-4.7	4.8	-1.5
All Latin America	6.4	1.6	8.7	5.2	-1.1	-3.7	3.4	2.1
Canada	5.7	- .1	3.3	0.2	0.4	- .3	2.8	-1.1

a Gross Rural Product.

TABLE 11

Share of Research and Extension in Government Expenditures[a]

R&E/GEA	1950	1960	1970	1980
	percent			
Argentina	5.1	10.0	6.7	8.6
Bolivia		8.8	1.3	
Brazil	1.0	1.4	1.7	11.6
Chile			1.6	
Colombia	5.1	3.3	1.5	1.1
Costa Rica			12.1	4.5
Mexico	0.6	2.2	1.2	1.9
Peru				
Venezuela			16.5	11.5

GEA/RGE	1950	1960	1975	CV 1950-1978
	percent			
Argentina	2.9	2.5	1.5	.22
Bolivia		4.2	23.3[b]	.41
Brazil	4.6	3.9	1.1	.52
Chile	3.3	4.0	5.5	.42
Colombia	4.9	4.5	5.6	.47
Costa Rica		1.8	2.9	.26
Mexico	16.6	4.5	10.1	.35
Peru	5.9	2.6	8.5	.37
Venezuela	5.5	7.0	8.6	.21

a R&E (research and extension); GEA (government expenditures on agriculture); TGE (total government expenditures); and CV (coefficient variation).

b 1970.

Source: Elias (1985:30).

Explanations of the level of research expenditures as a share of agricultural GDP (or GRP) can be obtained by using GNP per capita and the share of agriculture in GDP as exogenous variables in the following regressions. For the 14 Latin American countries in Table 10:

$$\frac{\text{Research expenditure}}{\text{GRP}} = \underset{(2.56)}{0.53} + \underset{(1.60)}{0.26}\ \frac{\text{GNP} \times 10^3}{\text{Population}} - \underset{(1.40)}{.16}\ \frac{\text{Ag GDP} \times 10}{\text{GDP}}$$

$n = 14, \quad R^2 = .64$

t ratios in parentheses

Adding Canada to the 14 Latin American countries:

$$\frac{\text{Research expenditure}}{\text{GRP}} = \underset{(2.41)}{0.47} + \underset{(7.50)}{0.29}\ \frac{\text{GNP} \times 10^3}{\text{Population}} - \underset{(1.81)}{0.14}\ \frac{\text{Ag GDP} \times 10}{\text{GDP}}$$

$n = 15, \quad R^2 = .91.$

Since Ag GDP/GDP decreases with GNP per capita, the results basically show that the main determinant of research expenditures per unit of agricultural GDP is the level of per capita income of a country. This, in turn, is consistent with the received idea that there is systematic underinvestment in agricultural research and that the main determinant of the level of that investment is the general level of income of a country. Figure 3 shows the relationship between research budgets per GRP and GDP per capita. Mexico again appears with an unexpectedly low research budget for its level of income compared to the other Latin American countries.

Research budgets are also characterized by a marked level of year-to-year instability. As the data in Table 12 indicate, the coefficient of variation (CV) for expenditures on R&E ranges from 16 to 41 percent, which is large. The study by Elias (1985) on government expenditures shows that there is more instability in public spending on agriculture than on health, transportation, or communications. Instability of expenditures on R&E is, however, neither systematically larger nor smaller than that of total GEA. In Table 12, half of the countries have CVs for R&E greater and half smaller than for GEA. Given the fact that agricultural research programs and the maturation of research teams require long gestation periods, this instability of public research budget is a major hurdle to the efficiency of public research institutions. To be more effective in generating results, these budgets would need to be sheltered from both the political process and fluctuations in public revenues.

No precise data exist on the allocation of research expenditures across commodities. Judd, Boyce, and Evenson (1986) have attempted to reconstruct these data by allocating total research

TABLE 12

Coefficient of Variation of Research and Extension and Government Expenditures on Agriculture

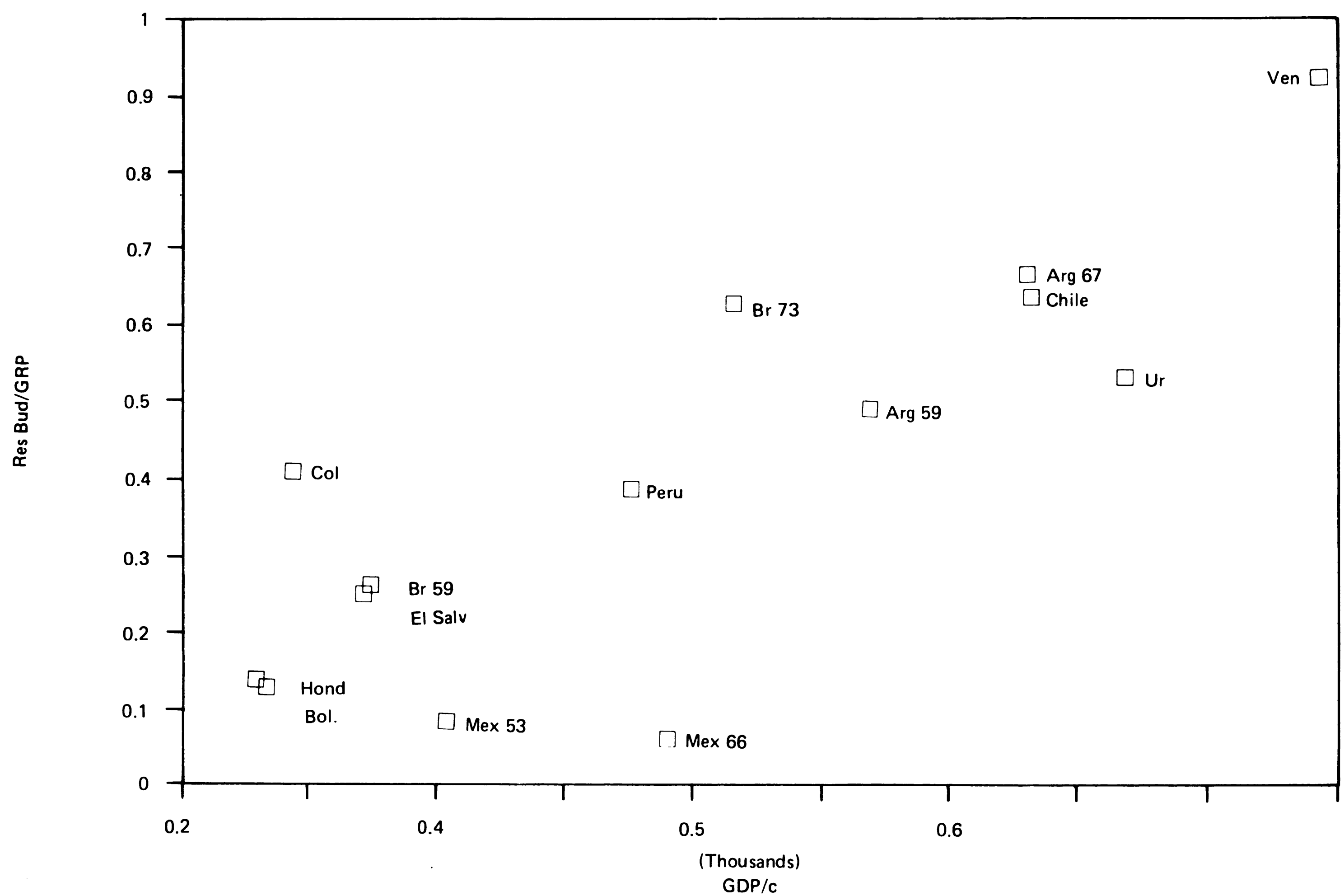
Country	Period	Coefficient of variation[a]	
		Research and extension	Government expenditures on agriculture
		percent	
Argentina	1950-1980	17.4	20.1
Brazil	1950-1977	85.0	16.1
	1950-1977[b]	15.9	8.7
Mexico	1950-1976	27.4	32.3
Peru	1950-1978	24.4	17.2
Chile	1950-1977	17.7	32.7
Colombia	1950-1980	40.9	27.3

a Calculated around linear time trend.

b With dummy variable for 1975-1977 to account for nonlinear increase in research and extension and government expenditures on agriculture.

Source: Elias (1985: Appendix).

FIGURE 3: RESEARCH BUDGET AS FUNCTION OF GDP/c



budgets proportionately to the number of research publications on each commodity. Dividing, in Table 13, these figures by the area planted in each commodity provides a measure of bias in research allocation across commodities. The dollars of research expenditures per hectare thus measured show a clear bias in favor of export crops (cotton, soybeans, sugar, bananas, and coffee) and against peasant crops (corn, beans, potatoes, and cassava), with commercial crops (wheat and rice) intermediate between the two. Research expenditures per hectare are 2.08 for export crops, 1.55 for commercial crops, and 0.66 for peasant crops.

TABLE 13

Allocation of Research Budget Across Commodities
Argentina, Brazil, Chile, Colombia, Mexico, Peru and Venezuela

1976	Public research expenditures	Area planted	Research expenditures
	1	2	3
	10^6 dollars (US) 1980	10^6 hectares	dollars per hectare
Commercial crops			
Wheat	21.26	11.73	1.81
Rice	8.39	7.45	1.13
Total			1.55
Export crops			
Cotton	2.89	3.00	0.96
Soybeans	16.78	7.06	2.38
Sugar	10.24	3.40	3.01
Bananas	1.68	9.24	0.18
Coffee	21.12	2.65	7.97
Total			2.08
Peasant crops			
Corn	7.01	22.34	0.31
Beans	7.77	6.12	1.27
Potatoes	3.97	0.83	4.80
Cassava	2.22	2.44	0.91
Total			0.66

Sources: Col. 1: Judd, Boyce, and Evenson (1986).

Col. 2: United Nations – FAO (1986), Production Statistics.

Issues in Public Sector Research

Biases and Inefficiencies in Resource Allocation

The Latin American farm structure tends to be highly skewed (dualistic), with the result that the allocation of research budgets across factors (landsaving versus laborsaving) and across commodities (where different farm sizes produce different commodities in different farming systems) has strong effects on the distribution of income. As was shown by the PROTAAL results, unless a commodity is of national significance as an urban wage good or as a source of foreign exchange earnings, allocation of research budgets to that commodity depends on the ability of producers to organize and influence the research institutes.

These two forms of decision-making in the allocation of research resources have created serious difficulties due to lack of systematic institutionalized linkages with both government and producers. By removing research from the ministries of agriculture and locating it in administratively independent national research institutes, more stability and self-determination were gained, but at the cost of a weak integration with national and sectoral economic policy. Only under crisis conditions does agricultural policy tend to bear on resource allocation toward national wage goods and foreign exchange earners. By failing to organize a representative constituency of farmers' interests cutting across commodities, farm sizes, and farming systems, resource allocation was left excessively prey to a few organized lobbies of medium and large producers.

The implication is the need to better articulate decision-making on research priorities with both economic and agricultural policy and with an organized representative constituency of producers' interests. The first requires incorporation in research councils of forward-looking economic planners and private sector suppliers of modern inputs. The second requires active incorporation of clientele groups in research councils and greater integration between experiment stations and field research.

Level and Stability of Funding

As we have seen, research budgets have fallen sharply in most countries since 1980 and have been highly unstable even during the phase of rapid growth. This is due to three problems.

One is the fact that domestic sources of funding tend to derive exclusively from the central government, with no participation (as opposed to, for instance, the U.S. model) given to state and local governments. The result is that research budgets are fully exposed to national economic and political forces with no possibility of domestic diversification of resource portfolios and of local compensatory appropriations. The implication is the need to open participation to decision-making **and** to budgetary contribution by state and local governments.

The second is that national research systems, which were initially created with substantial contributions from bilateral aid agencies, continued subsequently to depend for a significant share of their budgets on multilateral agencies such as the Inter-American Development Bank (IDB) and the World Bank. This has created several difficulties. There tends to exist a high level of discontinuity between phases of support by specific multilateral agencies. In addition, reliance on external resources has allowed research institutes to neglect the developing of local constituencies that could serve as sources of funds. This has contributed to distancing research institutes from local research needs, and to reducing social accountability.

Finally, both traditions and institutional mechanisms for interaction with private sector research and development are still in their infancy in many countries. This implies that public sector scientists are often constrained from participating in private sector research and manufacturing of modern inputs. Reciprocally, the private sector is often limited in its ability to finance specific research projects in the public research institutes. Important initiatives, however, have been taken to break this lack of public-private linkages. Producer associations have been funding public research in Peru, Ecuador, and Colombia. And INTA scientists in Argentina have been contracted by private manufacturers of inputs that embody new technological advances in seeds and agrochemicals. Significant innovations are left to be developed, to preserve the integrity, autonomy, and social responsibility of public sector research while also enhancing the flow of personnel and financial resources between public and private sectors.

Small Country Problem and Regional Cooperation

While economies of scale in research are likely to be large, a minimum threshold of expenditures to organize a meaningful commodity program is also a definite bottleneck for small countries, small commodities, and farming systems with a high degree of geographical or ecological specificity. This creates major difficulties for successful investment in research in many Central American and Caribbean countries, as well as in typically peasant crops and peasant farming systems even in large countries. In an interesting calculation, where a minimum research package of $309,000 (U.S.) is compared to a research budget equal to 1 percent of the gross value of production of a particular crop, Gamble and Trigo (1985) show that, out of 17 Central American and Caribbean countries, only the following could organize national commodity programs:

Commodities	Countries	Percentage of countries in Central America and the Caribbean
Maize	El Salvador, Guatemala, Honduras	18
Rice	Cuba, Dominican Republic, Guyana, Haiti, Costa Rica, Panama	35
Cassava	Cuba	6
Cotton	El Salvador, Guatemala, Honduras, Nicaragua	24
Beans	Guatemala, Nicaragua	12
Potatoes	None	0

The small country problem also applies to private sector research and to the delivery of modern inputs. Adaptation costs and market infrastructure are unlikely to be developed privately in situations were markets are too small.

This raises the important question of regional cooperation in research, of the sharing in funding (and control of free-riding tendencies), and of the distribution of the benefits from research among members of regional research institutes.

Regional cooperation programs such as CONOSUR and the **Programa Regional Cooperativo de la Papa** (PRECODEPA) show successful initiatives to solve the small country problem. CONOSUR is a program of exchange of information among the Southern Cone countries (Argentina, Chile, Uruguay, Paraguay, Brazil, and Bolivia) on research on five commodities (wheat, maize, sorghum, soybeans, and beef cattle). PRECODEPA is a program of research coordination among Mexico and Central American and Caribbean countries on potatoes. Both receive international funding assistance.

Dynamic Comparative Advantages and Research Priorities

In the context of upward adjustment in the real exchange rates and reallocation of resources toward tradable commodities, it is important to determine in which commodities Latin America has dynamic comparative advantages. To do so, we use in Tables 14, 15, 16, and 17, the data on Latin American shares of world exports for 1962-1964 and 1977-1979 prepared by Valdes (1984). They show in Table 15 that the highest shares in 1977-1979 are for coffee, cocoa, sugar, animal feeds, meat preparations, and vegetable oils. Revealed comparative advantages in commodity i at time t can be measured as:

$$RCA_{it} = \frac{\text{Share of LA exports of i in total world trade in i at t}}{\text{Share of LA in total world trade at t}}.$$

To get a measure of dynamic comparative advantages, we calculate the ratio and the corresponding average annual growth rate in RCA between 1962-1964 and 1977-1979. This shows in Table 14 that commodities for which revealed comparative advantages have grown the fastest are chocolate; flours; oil seeds; alcoholic beverages; and fruit, vegetable, and sugar preparations.

In terms of allocating research budgets to particular commodities, not only should dynamic comparative advantages be taken into account, but also two additional criteria: the importance of the product in total Latin American exports and the dynamics of growth of the market for the product. We thus have three criteria:

- Dynamics of comparative advantage of product i between 0 and t:

$$DCA_{0,t} = \left(\frac{\frac{E_i, LA}{E_i}}{\frac{E_{LA}}{E}} \right)_t \div \left(\frac{\frac{E_i, LA}{E_i}}{\frac{E_{LA}}{E}} \right)_0$$

where

$E_{i,LA}$ = Latin American exports of product i
E_i = world exports of product i
E_{LA} = total Latin American exports

and

E = total world exports.

- Importance of product i in total LA exports measured by the share of i in Latin American exports in reference year t':

$$SLA_{t'} = \left(\frac{E_{i,\,LA}}{E_{LA}} \right)_{t'} .$$

- Dynamics of the world market for product i measured by the change in the share of product i in world exports between 0 and t:

$$DSWE_{0,t} = \left(\frac{E_i}{E} \right)_t \div \left(\frac{E_i}{E} \right)_0 .$$

An overall criterion for research budget allocation is constructed with the product of these three indicators:

$$DCA_{0,t} \times SLA_{t'} \times DSWE_{0,t} .$$

The justification for this method of aggregation follows from the observation that, if the indicators of dynamic comparative advantage (DCA) and of dynamics of the world market (DSWE) are taken as fixed, the product computed above will give an estimation (Est) of the share of commodity i in Latin American exports in t years from the reference year t'. Indeed, from the identity

$$DCA_{0,t} \times SLA_0 \times DSWE_{0,t} = \left(\frac{E_{i,\,LA}}{E_{LA}} \right)_t ,$$

one derives

$$Est \left(\frac{E_{i,\,LA}}{E_{LA}} \right)_{t'+t} = DCA \times SLA_{t'} \times DSWE .$$

Calculation of this indicator was done using the 15-year period (1962-1966 to 1977-1979) to compute DCA and DSWE, and t' = 1977-1979 for the reference year. Transforming this into an index equal to 100 for the commodity with the highest research allocation criterion gives the result in the last column of Table 17. It shows that the tradable commodities that should receive the most attention in research are oilseeds, coffee, vegetable oils, cocoa, animal feeds, and vegetables. It is important that these types of calculations be updated to provide guidelines for research budget allocation.

TABLE 14

Dynamic Comparative Advantages (Ranking by Dynamic Comparative Advantages)

Commodities	LA Export 1977/79 (10^6 US$)	LA Export Share 1962/64 (percent)	LA Export Share 1977/79 (percent)	Revealed Comp. Adv. 1962/64	Revealed Comp. Adv. 1977/79	Dynamic Compar. Adv. 1962/64 (ratio)	Dynamic Compar. Adv. 1977/79 (an. rate) (percent)	Share in LA Exports 1977/79 (percent)	World Exp. Dynamics 1962/79	Res. Budget Allocat. (index)
Chocolate	47.1	0.1	4.5	0.014	0.9	62.2	31.7	0.066	4.17	83.04
Other Flours	0.7	0.1	0.9	0.014	0.2	12.4	18.3	0.001	0.94	0.06
Wheat Flour	25.9	0.4	3.1	0.055	0.6	10.7	17.1	0.036	1.1	2.07
Oilseeds	747.5	1.6	10.9	0.219	2.1	9.4	16.1	1.046	2.09	100.00
Alcoholic Beverages	57.5	0.2	1.1	0.027	0.2	7.6	14.5	0.080	2.39	7.10
Other Food Preparations	32.6	0.6	2.3	0.082	0.4	5.3	11.8	0.046	4.44	5.21
Soft Fixed Vegetable Oils	519.8	5.3	20.2	0.726	3.8	5.3	11.7	0.727	2.38	44.30
Fruit Preparations	309.7	5.5	15.6	0.753	3.0	3.9	9.5	0.433	2.21	18.24
Vegetable Preparations	66.6	1.6	4.3	0.219	0.8	3.7	9.1	0.093	2.55	4.29
Sugar Preparations	16.5	1.3	3.1	0.178	0.6	3.3	8.3	0.023	2.61	0.96
Vegetables Frozen or Chilled	408	4.4	10.3	0.603	2.0	3.2	8.1	0.571	1.96	17.59
Spices	42	4.9	10.7	0.671	2.0	3.0	7.6	0.059	1.77	1.53
Cocoa	901.5	13.2	28.2	1.808	5.3	3.0	7.5	1.261	1.75	31.67
Manufactured Tobacco	6.6	0.2	0.4	0.027	0.1	2.8	7.0	0.009	3.36	0.42
Unmanufactured Tobacco	286.3	5.8	11.6	0.795	2.2	2.8	7.0	0.401	1.35	7.26
Rice	78.3	2.1	4	0.288	0.8	2.6	6.7	0.110	1.43	2.00
Dried Fruits	19.1	2.1	3.4	0.288	0.6	2.2	5.5	0.027	1.24	0.36
Other Cereals	377	18.8	29.1	2.575	5.5	2.1	5.2	0.527	1.97	10.80
Cheese	32.4	1	1.4	0.137	0.3	1.9	4.5	0.045	2.67	1.14
Tea	40.3	2.8	3.7	0.384	0.7	1.8	4.1	0.056	1.15	0.58
Cereal Preparations	40.8	2	2.3	0.274	0.4	1.6	3.1	0.057	3.16	1.39
Crude Vegetable Materials	113.5	4	4.2	0.548	0.8	1.5	2.5	0.159	2.02	2.26
Meat Preparations	321.9	22.4	23.2	3.068	4.4	1.4	2.4	0.450	1.48	4.64
Crude Rubber	14.5	0.4	0.4	0.055	0.1	1.4	2.2	0.020	1.01	0.14
Sugar	929.3	26.7	26.3	3.658	5.0	1.4	2.1	1.300	1.53	13.16
Margerine	12.3	3.2	3.1	0.438	0.6	1.3	2.0	0.017	1.58	0.18
Wool	291.9	9.8	9.1	1.342	1.7	1.3	1.7	0.408	3.22	8.20
Fruits and Nuts	622.3	15.2	12.3	2.082	2.3	1.1	0.8	0.871	1.48	7.00
Animal Feeds	1 431.5	32.1	24.4	4.397	4.6	1.1	0.3	2.003	2.77	28.32
Other Vegetable Fibers	39.1	20.8	15.5	2.849	2.9	1.0	0.2	0.055	0.49	0.13
Coffee	4 156	81.9	60.8	11.219	11.5	1.0	0.2	5.814	1.73	50.15
Manufactured Fertilizer	30.1	1	0.7	0.137	0.1	1.0	-0.2	0.042	2.34	0.46
Other Crude Materials	31.4	6.8	4.4	0.932	0.8	0.9	-0.7	0.044	1.33	0.25
Wheat	413	8.3	5.2	1.137	1.0	0.9	-1.0	0.578	1.28	3.11
Animal Fats	46.5	8	4.2	1.096	0.8	0.7	-2.1	0.065	1.76	0.40
Cotton	549.4	28.1	14.6	3.849	2.8	0.7	-2.2	0.769	1	2.68
Live Animals	111.2	9.3	4.1	1.274	0.8	0.6	-3.2	0.156	1.78	0.82
Meat Fresh, Frozen, or Chilled	746.2	19.3	8.5	2.644	1.6	0.6	-3.3	1.044	2.37	7.32
Other Fixed Vegetable Oils	194.4	25	10.3	3.425	2.0	0.6	-3.7	0.272	2.06	1.55
Maize	570.3	22.1	9.1	3.027	1.7	0.6	-3.7	0.798	0.79	1.74
Meat Dried, Salted, or Smoked	7.1	1.3	0.5	0.178	0.1	0.5	-4.1	0.010	0.88	0.02
Processed Fats	24.9	10.1	3.8	1.384	0.7	0.5	-4.3	0.035	1.9	0.17
Crude Fertilizer	27.5	8.9	2.2	1.219	0.4	0.3	-6.9	0.038	1.86	0.12
Eggs	4.6	1.4	0.3	0.192	0.1	0.3	-7.8	0.006	2.42	0.02
Jute	0.1	0.6	0.1	0.082	0.0	0.2	-9.3	0.000	0.31	0.00
Butter	8.2	2.4	0.3	0.329	0.1	0.2	-11.0	0.011	1.59	0.02
Barley	2.7	4.6	0.5	0.630	0.1	0.2	-11.9	0.004	2.01	0.01
Hides	35	16.2	1.6	2.219	0.3	0.1	-12.4	0.049	1.48	0.05
Milk and Cream	1.2	0	0.3	0.000	0.1	0.0	0.0	0.002	1.08	0.00
All Latin American Exports		7.3	5.3							

TABLE 15

Dynamic Comparative Advantage (Ranking by Share in Latin American Exports)

Commodities	LA Exports 1977/79 (10^6 US$)	LA Export Share 1962/64 (percent)	LA Export Share 1977/79 (percent)	Revealed Compar. Adv. 1962/64	Revealed Compar. Adv. 1977/79	Dynamic Compar. Adv. 1962/64 (ratio) (percent)	Dynamic Compar. Adv. 1977/79 (an. rate) (percent)	Share in LA Exports 1977/79 (percent)	World Exp. Dynamics 1962-79	Res. Budget Allocat. (index)
Coffee	4 156	81.9	60.8	11.219	11.5	1.0	0.2	5.814	1.73	50.15
Animal Feeds	1 431.5	32.1	24.4	4.397	4.6	1.1	0.3	2.003	2.77	28.32
Sugar	929.3	26.7	26.3	3.658	5.0	1.4	2.1	1.300	1.53	13.16
Cocoa	901.5	13.2	28.2	1.808	5.3	3.0	7.5	1.261	1.75	31.67
Oilseeds	747.5	1.6	10.9	0.219	2.1	9.4	16.1	1.046	2.09	100.00
Meat Fresh, Frozen, or Chilled	746.2	19.3	8.5	2.644	1.6	0.6	-3.3	1.044	2.37	7.32
Fruits and Nuts	622.3	15.2	12.3	2.082	2.3	1.1	0.8	0.871	1.48	7.00
Maize	570.3	22.1	9.1	3.027	1.7	0.6	-3.7	0.798	0.79	1.74
Cotton	549.4	28.1	14.6	3.849	2.8	0.7	-2.2	0.769	1	2.68
Soft Fixed Vegetable Oils	519.8	5.3	20.2	0.726	3.8	5.3	11.7	0.727	2.38	44.30
Wheat	413	8.3	5.2	1.137	1.0	0.9	-1.0	0.578	1.28	3.11
Vegetables Frozen or Chilled	408	4.4	10.3	0.603	2.0	3.2	8.1	0.571	1.96	17.59
Other Cereals	377	18.8	29.1	2.575	5.5	2.1	5.2	0.527	1.97	10.80
Meat Preparations	321.9	22.4	23.2	3.068	4.4	1.4	2.4	0.450	1.48	4.64
Fruit Preparations	309.7	5.5	15.6	0.753	3.0	3.9	9.5	0.433	2.21	18.24
Wool	291.9	9.8	9.1	1.342	1.7	1.3	1.7	0.408	3.22	8.20
Unmanufactured Tobacco	286.3	5.8	11.6	0.795	2.2	2.8	7.0	0.401	1.35	7.26
Other Fixed Vegetable Oils	194.4	25	10.3	3.425	2.0	0.6	-3.7	0.272	2.06	1.55
Crude Vegetable Materials	113.5	4	4.2	0.548	0.8	1.5	2.5	0.159	2.02	2.26
Live Animals	111.2	9.3	4.1	1.274	0.8	0.6	-3.2	0.156	1.78	0.82
Rice	78.3	2.1	4	0.288	0.8	2.6	6.7	0.110	1.43	2.00
Vegetable Preparations	66.6	1.6	4.3	0.219	0.8	3.7	9.1	0.093	2.55	4.29
Alcoholic Beverages	57.5	0.2	1.1	0.027	0.2	7.6	14.5	0.080	2.39	7.10
Chocolate	47.1	0.1	4.5	0.014	0.852	62.2	31.7	0.066	4.17	83.04
Animal Fats	46.5	8	4.2	1.096	0.8	0.7	-2.1	0.065	1.76	0.40
Spices	42	4.9	10.7	0.671	2.0	3.0	7.6	0.059	1.77	1.53
Cereal Preparations	40.8	2	2.3	0.274	0.4	1.6	3.1	0.057	3.16	1.39
Tea	40.3	2.8	3.7	0.384	0.7	1.8	4.1	0.056	1.15	0.58
Other Vegetable Fibers	39.1	20.8	15.5	2.849	2.9	1.0	0.2	0.055	0.49	0.13
Hides	35	16.2	1.6	2.219	0.3	0.1	-12.4	0.049	1.48	0.05
Other Food Preparations	32.6	0.6	2.3	0.082	0.4	5.3	11.8	0.046	4.44	5.21
Cheese	32.4	1	1.4	0.137	0.3	1.9	4.5	0.045	2.67	1.14
Other Crude Materials	31.4	6.8	4.4	0.932	0.8	0.9	-0.7	0.044	1.33	0.25
Manufactured Fertilizer	30.1	1	0.7	0.137	0.1	1.0	-0.2	0.042	2.34	0.46
Crude Fertilizer	27.5	8.9	2.2	1.219	0.4	0.3	-6.9	0.038	1.86	0.12
Wheat Flour	25.9	0.4	3.1	0.055	0.6	10.7	17.1	0.036	1.1	2.07
Processed Fats	24.9	10.1	3.8	1.384	0.7	0.5	-4.3	0.035	1.9	0.17
Dried Fruits	19.1	2.1	3.4	0.288	0.6	2.2	5.5	0.027	1.24	0.36
Sugar Preparations	16.5	1.3	3.1	0.178	0.6	3.3	8.3	0.023	2.61	0.96
Crude Rubber	14.5	0.4	0.4	0.055	0.1	1.4	2.2	0.020	1.01	0.14
Margerine	12.3	3.2	3.1	0.438	0.6	1.3	2.0	0.017	1.58	0.18
Butter	8.2	2.4	0.3	0.329	0.1	0.2	-11.0	0.011	1.59	0.02
Meat Dried, Salted, or Smoked	7.1	1.3	0.5	0.178	0.1	0.5	-4.1	0.010	0.88	0.02
Manufactured Tobacco	6.6	0.2	0.4	0.027	0.1	2.8	7.0	0.009	3.36	0.42
Eggs	4.6	1.4	0.3	0.192	0.1	0.3	-7.8	0.006	2.42	0.02
Barley	2.7	4.6	0.5	0.630	0.1	0.2	-11.9	0.004	2.01	0.01
Milk and Cream	1.2	0	0.3	0.000	0.1	0.0	0.0	0.002	1.08	0.00
Other Flours	0.7	0.1	0.9	0.014	0.2	12.4	18.3	0.001	0.94	0.06
Jute	0.1	0.6	0.1	0.082	0.0	0.2	-9.3	0.000	0.31	0.00
All Latin American Exports		7.3	5.3							

TABLE 16

Dynamic Comparative Advantage (Ranking by World Export Dynamics 1962-79)

Commodities	LA Exports 1977/79 (10^6 US$)	LA Export Share 1962/64 (percent)	LA Export Share 1977/79 (percent)	Revealed Compar. Adv. 1962/64	Revealed Compar. Adv. 1977/79	Dynamic Compar. Adv. 1962/64 (ratio) (percent)	Dynamic Compar. Adv. 1977/79 (an. rate) (percent)	Share in LA Exports 1977/79 (percent)	World Exp. Dynamics 1962-79	Res. Budget Allocat. (index)
Other Food Preparations	32.6	0.6	2.3	0.082	0.4	5.3	11.8	0.046	4.44	5.21
Chocolate	47.1	0.1	4.5	0.014	0.852	62.2	31.7	0.066	4.17	83.04
Manufactured Tobacco	6.6	0.2	0.4	0.027	0.1	2.8	7.0	0.009	3.36	0.42
Wool	291.9	9.8	9.1	1.342	1.7	1.3	1.7	0.408	3.22	8.20
Cereal Preparations	40.8	2	2.3	0.274	0.4	1.6	3.1	0.057	3.16	1.39
Animal Feeds	1 431.5	32.1	24.4	4.397	4.6	1.1	0.3	2.003	2.77	28.32
Cheese	32.4	1	1.4	0.137	0.3	1.9	4.5	0.045	2.67	1.14
Sugar Preparations	16.5	1.3	3.1	0.178	0.6	3.3	8.3	0.023	2.61	0.96
Vegetable Preparations	66.6	1.6	4.3	0.219	0.8	3.7	9.1	0.093	2.55	4.29
Eggs	4.6	1.4	0.3	0.192	0.1	0.3	-7.8	0.006	2.42	0.02
Alcoholic Beverages	57.5	0.2	1.1	0.027	0.2	7.6	14.5	0.080	2.39	7.10
Soft Fixed Vegetable Oils	519.8	5.3	20.2	0.726	3.8	5.3	11.7	0.727	2.38	44.30
Meat Fresh, Frozen, or Chilled	746.2	19.3	8.5	2.644	1.6	0.6	-3.3	1.044	2.37	7.32
Manufactured Fertilizer	30.1	1	0.7	0.137	0.1	1.0	-0.2	0.042	2.34	0.46
Fruit Preparations	309.7	5.5	15.6	0.753	3.0	3.9	9.5	0.433	2.21	18.24
Oilseeds	747.5	1.6	10.9	0.219	2.1	9.4	16.1	1.046	2.09	100.00
Other Fixed Vegetable Oils	194.4	25	10.3	3.425	2.0	0.6	-3.7	0.272	2.06	1.55
Crude Vegetable Materials	113.5	4	4.2	0.548	0.8	1.5	2.5	0.159	2.02	2.26
Barley	2.7	4.6	0.5	0.630	0.1	0.2	-11.9	0.004	2.01	0.01
Other Cereals	377	18.8	29.1	2.575	5.5	2.1	5.2	0.527	1.97	10.80
Vegetables Frozen or Chilled	408	4.4	10.3	0.603	2.0	3.2	8.1	0.571	1.96	17.59
Processed Fats	24.9	10.1	3.8	1.384	0.7	0.5	-4.3	0.035	1.9	0.17
Crude Fertilizer	27.5	8.9	2.2	1.219	0.4	0.3	-6.9	0.038	1.86	0.12
Live Animals	111.2	9.3	4.1	1.274	0.8	0.6	-3.2	0.156	1.78	0.82
Spices	42	4.9	10.7	0.671	2.0	3.0	7.6	0.059	1.77	1.53
Animal Fats	46.5	8	4.2	1.096	0.8	0.7	-2.1	0.065	1.76	0.40
Cocoa	901.5	13.2	28.2	1.808	5.3	3.0	7.5	1.261	1.75	31.67
Coffee	4 156	81.9	60.8	11.219	11.5	1.0	0.2	5.814	1.73	50.15
Butter	8.2	2.4	0.3	0.329	0.1	0.2	-11.0	0.011	1.59	0.02
Margerine	12.3	3.2	3.1	0.438	0.6	1.3	2.0	0.017	1.58	0.18
Sugar	929.3	26.7	26.3	3.658	5.0	1.4	2.1	1.300	1.53	13.16
Meat Preparations	321.9	22.4	23.2	3.068	4.4	1.4	2.4	0.450	1.48	4.64
Hides	35	16.2	1.6	2.219	0.3	0.1	-12.4	0.049	1.48	0.05
Fruits and Nuts	622.3	15.2	12.3	2.082	2.3	1.1	0.8	0.871	1.48	7.00
Rice	78.3	2.1	4	0.288	0.8	2.6	6.7	0.110	1.43	2.00
Unmanufactured Tobacco	286.3	5.8	11.6	0.795	2.2	2.8	7.0	0.401	1.35	7.26
Other Crude Materials	31.4	6.8	4.4	0.932	0.8	0.9	-0.7	0.044	1.33	0.25
Wheat	413	8.3	5.2	1.137	1.0	0.9	-1.0	0.578	1.28	3.11
Dried Fruits	19.1	2.1	3.4	0.288	0.6	2.2	5.5	0.027	1.24	0.36
Tea	40.3	2.8	3.7	0.384	0.7	1.8	4.1	0.056	1.15	0.58
Wheat Flour	25.9	0.4	3.1	0.055	0.6	10.7	17.1	0.036	1.1	2.07
Milk and Cream	1.2	0	0.3	0.000	0.1	0.0	0.0	0.002	1.08	0.00
Crude Rubber	14.5	0.4	0.4	0.055	0.1	1.4	2.2	0.020	1.01	0.14
Cotton	549.4	28.1	14.6	3.849	2.8	0.7	-2.2	0.769	1	2.68
Other Flours	0.7	0.1	0.9	0.014	0.2	12.4	18.3	0.001	0.94	0.06
Meat Dried, Salted, or Smoked	7.1	1.3	0.5	0.178	0.1	0.5	-4.1	0.010	0.88	0.02
Maize	570.3	22.1	9.1	3.027	1.7	0.6	-3.7	0.798	0.79	1.74
Other Vegetable Fibers	39.1	20.8	15.5	2.849	2.9	1.0	0.2	0.055	0.49	0.13
Jute	0.1	0.6	0.1	0.082	0.0	0.2	-9.3	0.000	0.31	0.00
All Latin American Exports		7.3	5.3							

TABLE 17

Dynamic Comparative Advantage (Ranking by Research Budget Allocation)

Commodities	LA Export	LA Export Share		Revealed Comp. Adv.		Dynamic Compar. Adv.		Share in LA Exports	World Exp. Dynamics	Res. Budget Allocat.
	1977/79 (10^6 US$)	1962/64 (percent)	1977/79	1962/64	1977/79	1962/64 (ratio)	1977/79 (an. rate) (percent)	1977/79 (percent)	1962/79	(index)
Oilseeds	747.5	1.6	10.9	0.219	2.1	9.4	16.1	1.046	2.09	100.00
Chocolate	47.1	0.1	4.5	0.014	0.852	62.2	31.7	0.066	4.17	83.04
Coffee	4 156	81.9	60.8	11.219	11.5	1.0	0.2	5.814	1.73	50.15
Soft Fixed Vegetable Oils	519.8	5.3	20.2	0.726	3.8	5.3	11.7	0.727	2.38	44.30
Cocoa	901.5	13.2	28.2	1.808	5.3	3.0	7.5	1.261	1.75	31.67
Animal Feeds	1 431.5	32.1	24.4	4.397	4.6	1.1	0.3	2.003	2.77	28.32
Fruit Preparations	309.7	5.5	15.6	0.753	3.0	3.9	9.5	0.433	2.21	18.24
Vegetables Frozen or Chilled	408	4.4	10.3	0.603	2.0	3.2	8.1	0.571	1.96	17.59
Sugar	929.3	26.7	26.3	3.658	5.0	1.4	2.1	1.300	1.53	13.16
Other Cereals	377	18.8	29.1	2.575	5.5	2.1	5.2	0.527	1.97	10.80
Wool	291.9	9.8	9.1	1.342	1.7	1.3	1.7	0.408	3.22	8.20
Meat Fresh, Frozen, or Chilled	746.2	19.3	8.5	2.644	1.6	0.6	-3.3	1.044	2.37	7.32
Unmanufactured Tobacco	286.3	5.8	11.6	0.795	2.2	2.8	7.0	0.401	1.35	7.26
Alcoholic Beverages	57.5	0.2	1.1	0.027	0.2	7.6	14.5	0.080	2.39	7.10
Fruits and Nuts	622.3	15.2	12.3	2.082	2.3	1.1	0.8	0.871	1.48	7.00
Other Food Preparations	32.6	0.6	2.3	0.082	0.4	5.3	11.8	0.046	4.44	5.21
Meat Preparations	321.9	22.4	23.2	3.068	4.4	1.4	2.4	0.450	1.48	4.64
Vegetable Preparations	66.6	1.6	4.3	0.219	0.8	3.7	9.1	0.093	2.55	4.29
Wheat	413	8.3	5.2	1.137	1.0	0.9	-1.0	0.578	1.28	3.11
Cotton	549.4	28.1	14.6	3.849	2.8	0.7	-2.2	0.769	1	2.68
Crude Vegetable Materials	113.5	4	4.2	0.548	0.8	1.5	2.5	0.159	2.02	2.26
Wheat Flour	25.9	0.4	3.1	0.055	0.6	10.7	17.1	0.036	1.1	2.07
Rice	78.3	2.1	4	0.288	0.8	2.6	6.7	0.110	1.43	2.00
Maize	570.3	22.1	9.1	3.027	1.7	0.6	-3.7	0.798	0.79	1.74
Other Fixed Vegetable Oils	194.4	25	10.3	3.425	2.0	0.6	-3.7	0.272	2.06	1.55
Spices	42	4.9	10.7	0.671	2.0	3.0	7.6	0.059	1.77	1.53
Cereal Preparations	40.8	2	2.3	0.274	0.4	1.6	3.1	0.057	3.16	1.39
Cheese	32.4	1	1.4	0.137	0.3	1.9	4.5	0.045	2.67	1.14
Sugar Preparations	16.5	1.3	3.1	0.178	0.6	3.3	8.3	0.023	2.61	0.96
Live Animals	111.2	9.3	4.1	1.274	0.8	0.6	-3.2	0.156	1.78	0.82
Tea	40.3	2.8	3.7	0.384	0.7	1.8	4.1	0.056	1.15	0.58
Manufactured Fertilizer	30.1	1	0.7	0.137	0.1	1.0	-0.2	0.042	2.34	0.46
Manufactured Tobacco	6.6	0.2	0.4	0.027	0.1	2.8	7.0	0.009	3.36	0.42
Animal Fats	46.5	8	4.2	1.096	0.8	0.7	-2.1	0.065	1.76	0.40
Dried Fruits	19.1	2.1	3.4	0.288	0.6	2.2	5.5	0.027	1.24	0.36
Other Crude Materials	31.4	6.8	4.4	0.932	0.8	0.9	-0.7	0.044	1.33	0.25
Margerine	12.3	3.2	3.1	0.438	0.6	1.3	2.0	0.017	1.58	0.18
Processed Fats	24.9	10.1	3.8	1.384	0.7	0.5	-4.3	0.035	1.9	0.17
Crude Rubber	14.5	0.4	0.4	0.055	0.1	1.4	2.2	0.020	1.01	0.14
Other Vegetable Fibers	39.1	20.8	15.5	2.849	2.9	1.0	0.2	0.055	0.49	0.13
Crude Fertilizer	27.5	8.9	2.2	1.219	0.4	0.3	-6.9	0.038	1.86	0.12
Other Flours	0.7	0.1	0.9	0.014	0.2	12.4	18.3	0.001	0.94	0.06
Hides	35	16.2	1.6	2.219	0.3	0.1	-12.4	0.049	1.48	0.05
Meat Dried, Salted, or Smoked	7.1	1.3	0.5	0.178	0 1	0.5	-4.1	0.010	0.88	0.02
Eggs	4.6	1.4	0.3	0.192	0.1	0.3	-7.8	0.006	2.42	0.02
Butter	8.2	2.4	0.3	0.329	0.1	0.2	-11.0	0.011	1.59	0.02
Barley	2.7	4.6	0.5	0.630	0.1	0.2	-11.9	0.004	2.01	0.01
Jute	0.1	0.6	0.1	0.082	0.0	0.2	-9.3	0.000	0.31	0.00
Milk and Cream	1.2	0	0.3	0.000	0.1	0.0	0.0	0.002	1.08	0.00
All Latin American Exports		7.3	5.3							

Comparison of this index with the actual research budget expenditure reported in Table 13 shows some correspondence in the high priority given to oilseeds, coffee, and sugar and an intermediate priority given to rice. Wheat seems to have benefited from a higher research budget than the index of allocation computed above would support. Cotton, on the other hand, received relatively little research budget. The limitation of such an analysis is its concentration on export crops and the exclusion of most peasant crops. For peasant crops, the justification for research is based on criteria of adequacy of national food supply, improvement of nutritional status of specific groups, and equity consideration - not on comparative advantage in trade.

Peasant Farming Systems and Rural Development

With a highly dualistic land tenure system and lack of employment opportunities in the urban-industrial sector, the number of small farms in Latin America has about doubled in the last 30 years, although the average size of these farms has likely declined (Table 18). These small farms are of basically two types. One is family farms with enough productive resources to fully employ household members and, if given access to supportive institutions and with appropriate price incentives, to rapidly adopt technological innovations. The other is subfamily farms which serve as a reservoir of surplus populations, and where nonfarm sources of income are a necessary complement to home production, typically accounting for 50 percent or more of total household income (Table 19). Even if improved technology will not solve the problem of poverty in this second type of farm households until they are provided access to either more land or to more employment and migration opportunities, the productivity of land use is an important determinant of household welfare. For both family and subfamily farms, specific technological advances must be provided by public sector research. This is justified not only on welfare grounds but also because these farms are often important sources of a marketed surplus of wage-goods and sometimes (but rarely in Latin America) export crops.

Developing new technologies for resource-poor farmers is a major challenge that cannot be written off in Latin America. The technological difficulties originate in several factors:

• Technological advances for small farmers cannot be made piecemeal, but as part of a comprehensive farming systems approach (Altieri and Anderson 1986; Hildebrand 1979). This requires an interdisciplinary understanding of what small farmers are doing, why they have chosen their current practices, and what would be required for them to modify their farming systems. It requires taking science to the farmers' fields, controlling highly multidimensional systems, and enlisting local participation. It also implies satisfying simultaneously a multiplicity of objectives, including productivity, stability, sustainability, and equity. In general, it is clear that research on farming systems is much more complex than research on commercial crops.

• Farming systems research (FSR) tends to be highly location and household specific, with the implication that the field of application of the results obtained is small. With high research costs and limited geographical applicability of results, the rate of return on investments in FSR, consequently, will be low, unless carefully targeted.

• Successful technological developments need complementary programs of integrated rural development (IRD) to insure diffusion among small farmers. This requires difficult institutional coordination of research efforts providing access for small farmers to information, credit, modern inputs, and markets for their products. Except for more privileged family farmers, IRD programs have, as of yet, rarely been successful in Latin America.

TABLE 18

Number and Average Size of Small Farms Over Time

Country	Years	Maximum farm size	Number of farms	Percent of farms	Percent of area	Average farm size
				percent		hectares
Argentina	1914	25 hectares	100 836	33.0	1.0	9.6
	1947		161 452	34.3	1.0	10.9
	1952		235 953	41.8	1.1	9.2
	1960		181 404	38.5	1.0	9.7
	1969		226 065	42.0	0.9	8.9
Bolivia	1950	5 hectares		59.3	0.2	
Brazil	1940	5 hectares		21.8	0.5	
	1950		458 676	22.2	0.5	2.6
	1960		1 029 336	30.8	1.0	2.5
	1970		1 800 243	36.6	1.3	2.2
	1975		1 911 730	38.3	1.2	2.1
	1980		1 888 196	36.6	1.1	2.1
	1950	10 hectares	710 934	34.4	1.3	4.3
	1960		1 495 020	44.4	2.3	4.0
	1970		2 519 630	51.2	3.1	3.6
	1975		2 601 860	52.1	2.8	3.5
	1980		2 598 019	50.4	2.5	3.5
Chile	1955	10 hectares	75 627	61.0	0.8	2.9
	1965		156 769	62.0	1.4	2.8
	1965	5 BIH	189 529	81.0	9.7	
	1972			79.0	9.7	
	1976			71.0	9.7	
	1979	5.1 BIH	254 925	75.0	14.6	
Colombia	1954	10 hectares	648 115	71.0	6.9	2.9
	1960		925 750	77.0	8.8	2.6
	1970		859 884	73.0	7.2	2.6
Costa Rica	1955	10.5 hectares	25 575	54.0	5.2	3.8
	1963		34 038	53.0	4.8	3.8
	1963	10 hectares	30 377	50.0	5.0	4.1
	1973		29 927	48.0	4.0	3.9
Dominican Republic	1971	5 hectares	235 000	77.1	12.9	1.5
	1981		314 700	81.7	12.2	1.0
Ecuador	1954	5 hectares	212 153	82.0	11.0	1.6
	1974		298 965	77.0	13.0	1.3
Ecuador Sierra	1954	10 hectares	234 596	90.0	16.0	2.1
	1974		280 974	87.0	18.0	1.9
El Salvador	1950	5 hectares	140 473	80.7	12.4	1.4
	1961		193 298	85.3	15.5	1.3
	1971		234 941	86.9	19.6	1.2
Guatemala	1950	7 hectares	308 000	88.0	14.0	2.5
	1964		364 879	88.0	19.0	2.5
	1979		547 574	90.0	16.0	1.8

TABLE 18 – continued

Country	Years	Maximum farm size	Number of farms	Percent of farms	Percent of area	Average farm size
				percent		hectares
Haiti	1971	5 hectares	593 325	96.0	78.0	1.1
Honduras	1952	5 hectares	88 997	57.0	8.0	2.3
	1966			47.0	6.0	
	1974		124 781	64.0	9.0	1.9
Jamaica	1969	5 hectares		91.3	26.5	
Mexico	1950	5 hectares,	1 020 747	39.2	7.6	1.5
	1960	private[a]	928 717	34.2	6.1	1.6
	1970		678 214	25.2	5.0	1.7
	1950	4 hectares,	569 866	21.9	6.1	2.1
	1960	ejido[a]	668 162	24.6	5.9	2.1
	1970		951 878	35.6	8.6	2.1
Nicaragua	1952	7 hectares	17 943	34.8	2.3	3.0
	1963		51 936	50.8	3.5	2.6
	1971		37 500	43.8	2.2	3.5
	1978				2.0	
	1983				5.4	
Panama	1950	5 hectares	44 442	52.0	8.3	2.2
	1961		43 692	45.7	5.3	2.2
	1971		41 307	45.4	3.7	1.8
Paraguay	1943	5 hectares	45 426	48.1	8.0	2.7
	1956		68 714	45.9	1.0	2.4
	1961		74 559	46.4		
Peru	1961	5 hectares	699 427	82.9	5.2	1.3
	1972		1 083 775	77.9	6.6	1.4
Uruguay	1951	20 hectares	35 841	42.0	1.8	8.3
	1961		39 829	45.8	1.9	8.0
Venezuela	1950	5 hectares	125 990	54.7	1.2	2.1
	1961		155 617	49.3	1.4	2.3
	1971		121 778	42.3	1.0	2.2
Latin America[b]	1950	Small farms	4 134 000			2.4
	1980		7 949 000			2.1

a Refers to cultivated land.

b Based on linear extrapolations from the nearest two censuses and excluding Paraguay and Uruguay for which recent information is not available.

Source: **Agricultural Censuses,** various years.

• Lack of effective small farmer lobbies implies that research budgets are seldom allocated to FSR. Reliance on foreign assistance budgets breeds significant instability in what should be sustained, long-run efforts.

Major technological efforts are, consequently, left to be done if we want to increase the productivity of resource poor farmers. At the same time, technology is, at best, one element of a solution to rural poverty; these efforts, consequently, need to be integrated in a broad-based approach to the problem of rural poverty.

TABLE 19

Sources of Income

Country and farm size	Year	Share of farm households	Shares of income derived from:			Total household annual net income
			Farm activities	Wages	Other activities	
hectares		percent				dollars (US)
Cajamarca (Peru)						
0- 3.5	1973	72	23	50	27	223
3.5-11.0		17	55	24	21	270
Puebla (Mexico)						
0-4	1970	71	32	58	11	393
4-8		25	64	32	3	675
Garcia Rovira (Colombia)						
0-4	1972	20	79	16	5	365
4-10		45	86	10	4	543
South Bolivia						
0-5	1976-77	67	38	62		320
5-10		15	63	37		373
Region IV (Chile)						
0-2	1976	59	36	48	16	848
2-5		25	73	21	6	1 941
Vertentes (Brazil)						
0-10	1979	16	a	56		
10-20		49		15		
Northwest Altiplano (Guatemala)						
0- 1.4	1978	63	24	63	13	
1.4- 3.5		22	42	47	11	
3.5-44.8		15	58	34	8	
El Salvador						
0-1	1975	49	59	31	10	
1-2		22	75	19	6	
Ecuador						
0- 1	1974	34	23	63	14	561
1- 5		43	57	35	8	579
5-20		16	79	12	9	1 218
Ecuador–Sierra						
0- 1	1974		19	54	27	
1- 5			52	36	12	
5-20			71	12	17	
Ecuador–Coast						
0- 1	1974		32	53	15	
1- 5			60	31	9	
5-20			77	14	9	
Chamula (Mexico)						
	1970-1974		11	89		240

a Blanks indicate no data available.

Sources: Deere and de Janvry (1979:601-611); De Janvry (1981:245); Deere and Wasserstrom (1981); Monardes (1977); Da Silva (1983); Hintermeister (1985:37); Deere and Diskin (1984:6); Commander and Peek (1983:33); Ortega (1982:94).

5

ROLE AND PERFORMANCE OF THE PRIVATE SECTOR

Rising Importance of the Private Sector

As agriculture has developed in the twentieth century, production has increasingly been moved off the farm and technology delivered embodied in purchased inputs. It is now estimated that, in the United States, only 10 percent of the value added of food is actually produced on the farm, whereas 40 percent of the value is added by purchased inputs and the remaining 50 percent added after the farm in processing and marketing. Put differently, between 1979 and 1975, the value of inputs produced on the farm in the United States declined by 50 percent while the value of off-farm inputs tripled (Levins and Lewontin 1985).

The adoption of these inputs occurred in a series of stages which have been shown to correspond to shifting relative factor prices (Ruttan 1983). In particular, chemical fertilizers and pesticides were massively adopted after World War II, with agricultural chemical use in the United States increasing seven times between 1946 and 1976. This was triggered both by falling relative prices of chemicals and fertilizers in the United States, thanks to the enormous chemical plant capacity built by the government during World War II, and by strong effective demand for food in both the United States and European export markets (Levins and Lewontin 1985).

The transfer of this technology to Latin America from the more developed countries has also occurred in stages which responded to relative factor prices, to the development of necessary infrastructure, and to the previous adoption of other technology (Piñeiro 1984). Agricultural technology is often adopted in chains or bundles and is a cumulative process. For example, hybrid varieties of grains are usually bred to utilize ever-larger amounts of fertilizers.

While the transfer of agronomic techniques and open-pollinated seeds largely took place through the public sector, the private sector assumes a more important role in developing and delivering agricultural technology in Latin America as technology becomes increasingly commodified in purchased inputs. As with other industries, the agricultural input industries often developed in stages: first, importing finished products; then manufacturing or assembling them within the country using imported technology; and, finally, innovating products or processes (de Obschatko, Piñeiro, and Jacobs 1985).

In the machinery sector, really only Argentina has reached the final stage, with Brazil perhaps nearing it. This industry was created in the larger countries through import substitution policies, state investment, and subsidized loans. Smaller countries are entirely dependent on imports and only Brazil is a net exporter of tractors (FAO). Because of the crisis and low availability of credit, agricultural machinery has become an unprofitable sector throughout the

Western Hemisphere. The resultant decapitalization of agriculture as farms run down machinery should be monitored. Little R&D has been accomplished in any country except Argentina, and the present restructuring could be utilized to address this.

In the agrochemical sector, most countries import substantial quantities from Europe and the United States via TNCs, although the crisis has accelerated the trend to mix chemicals, utilizing as many local inputs as possible. Substantial excess formulation capacity was built during the 1970s (Maltby 1980). Table 20 shows the trade data for finished pesticides, 1980-1984, in 15 countries. Only Brazil and Guatemala are net exporters, Brazil having turned a $115 million deficit in 1978 into a $56 million trade surplus by 1984 through price and export subsidies (Maltby 1980) (Table 21). Colombia has also significantly increased exports through policy measures. The total pesticide trade deficit from the region was stagnant during 1977-1983, but increased rapidly in 1984-85 (Table 21).

In terms of comparative advantage, it may not be unwise to import such inputs in support of export crops. In Latin America, most pesticides as applied to a small number of

TABLE 20

Pesticide Trade

Country	Average imports 1980-1984	Average exports 1980-1984
	1 000 dollars (US)	
Costa Rica	36 946	10 201
Salvador	14 126	4 425
Guatemala	18 308	26 597
Honduras	26 362	126
Mexico	19 735	3 179
Nicaragua	22 279	823
Panama	18 812	560
Argentina	56 352	1 870
Bolivia	5 736	0
Brazil	10 879	41 323
Chile	16 782	1 345
Colombia	26 587	22 732
Ecuador	23 762	449
Peru	13 908	700
Venezuela	10 151	499
Latin America	430 122	121 134

Source: United Nations – FAO (various years).

TABLE 21

Pesticides: Exports and Imports

Year	Brazil	Mexico	Latin America
	1 000 dollars (US)		
1970	- 18 395	- 2 707	-112 205
1971	- 18 712	- 6 774	95 768
1972	- 37 411	- 6 518	-122 596
1973	- 73 143	- 6 287	-177 035
1974	- 87 475	- 9 048	-213 109
1975	- 94 589	- 9 646	-289 784
1976	-104 326	- 8 257	-291 694
1977	-102 499	-15 444	-315 755
1978	-114 722	- 7 638	-342 992
1979	- 30 593	- 8 438	-307 893
1980	- 3 671	-13 903	-296 329
1981	23 939	-15 710	-314 095
1982	35 168	-16 500[a]	-280 036
1983	40 471	-17 200[a]	-315 049
1984	56 310	-19 465[a]	-339 433
1985	44 812[a]	-20 400[a]	-408 572

a Estimated.

Source: United Nations – FAO (various years).

crops, including important exports, mainly coffee, sugar, tobacco, cotton, rice, soya, and fruits and vegetables; herbicides are applied principally in sugar, cotton, rice, and soya (Maltby 1980). Nevertheless, several factors argue for altered policy measures: First, there is considerable evidence that excessive amounts of chemicals are applied in many areas (Repetto 1985; Wright 1986). This creates a larger cost to society than is necessary. Second, such application is encouraged in many Latin American countries by subsidies to chemical use. Repetto estimated the subsidy to pesticides in 1982 as U.S. $12 million in Honduras, $14 million in Ecuador, and $69 million in Colombia. Such subsidies skew technology toward chemicals. Third, this bias toward excessive chemical use is internally contradictory in that it creates a resistance in pests more rapidly and destroys predators. As a result, increasing amounts of chemicals have to be applied (the pesticide "treadmill") to maintain quality and yields at ever higher costs until certain crops can no longer be grown in certain regions at all. This has already occurred in many areas with cotton (Wright 1986).

Removing subsidies from chemicals and embarking on research into alternative methods would both decrease government expenditures and improve the competitiveness and sustainability of Latin American export agriculture. For example, probably over one-half of all chemicals are used on cotton alone in Latin America (Maltby 1980). A serious effort to apply and improve the integrated pest management techniques for cotton developed in the United States would make cotton production in Latin America more sustainable, less hazardous, and would contribute significantly to the balance of payments in most countries. At present the chemical industry is dominated by TNCs who will not make this shift but, as we discuss below in the section on biotechnology, who may not support a chemical agriculture in the long run either.

Shift to Private Sector

At the same time as the private sector has become more important in delivering agricultural technology in Latin America, it has also taken over certain R&D functions from public institutions in the more developed countries. Ruttan estimated the private sector's share of all R&D spending in support of the U.S. food system in 1979 at 65 percent or over $2 billion per year - up from 55 percent in 1965.

In particular, the advent of biotechnology and patent protection for plant breeding has led to the absorption of seed companies by large chemical/ pharmaceutical firms and the transfer of applied plant breeding out of the universities in the United States. This will increase the emphasis on breeding hybrid varieties, and it will reduce the publicly available material which Latin American researchers have used for their adaptive work. Thus, either Latin America must develop the capability to take basic research and develop applied technology itself, or it will have to depend on the TNCs to transfer it.

A dual strategy would appear appropriate and in line with the dual structure of Latin American agriculture. On the one hand, little research has been done for small holders, although criticism of the Green Revolution and the IARCs has spurred farming systems research (Ruttan 1983). This should be complemented by breeding efforts on open-pollinated varieties. Scientific evidence suggests that, if the same effort had been put into such varieties as was devoted to hybrids since the 1930s, the open-pollinated varieties would now perform as well or better (Levins and Lewontin 1985). Similarly, greater effort in biological pest and disease control is particularly appropriate to small holder polycultural agriculture. All of this research would tend to raise productivity without requiring large quantities of purchased inputs, and it would have beneficial spillover effects in knowledge terms as large-scale commercial agriculture moves away from chemical-intensive practices.

On the other hand, to the extent the TNCs are truly international corporations and have research facilities around the world, the privatization of applied research may actually benefit Latin America in world competition by making the same technology available to everyone at the same time at the same price. This would remove the advantage that developed countries now have in terms of early adoption of new technologies, but it will mean that distribution will be through TNC marketing networks. Thus, to compete successfully in export markets, countries should encourage and cooperate with TNC research and assure that local commercial agriculture has access to their marketing networks. By giving the TNCs the correct incentives, Latin America can gain access to a large R&D structure which they otherwise could not afford, using it to exploit their cost advantages in export markets.

Small Country Problem

As Ruttan has pointed out, the cost of adapting a variety to a small region is not terribly different than the cost for a large region, which means the cost per hectare of research in a small country/region will be higher. As a result, while small countries are more dependent on the TNCs to deliver agricultural technology, since they lack the resources to fund much public research, there is less incentive to the firms to develop any specific technology for them because markets are limited and adaptive costs are higher.

This would appear to argue for a relatively higher level of investment in agricultural research by small countries. As agriculture moves away from crude chemical pest and disease control to more selective and sophisticated techniques - whether biotechnological or ecological controls - such research will become increasingly important. Chemicals have broad markets because they are broadly destructive and are relatively easily transferred to small countries. However, biotechnology that seeks to alter (plant) genetics for pest resistance must select the pests beforehand; pests important only in small markets will not be considered by private firms. Similarly, ecological controls are site specific, and all countries will have to have personnel capable of developing integrated plans.

While international consulting firms that offer such services are already evolving, they are expensive and would merely increase the balance-of-payments problems associated with current imports of manufactured inputs. Instead, as we shift toward a more knowledge-intensive agriculture, small countries have the opportunity to invest in a human/scientific infrastructure which has several advantages: First, because human capital is highly divisible, it does not require large fixed capital expenditures inappropriate for small countries (such economies of scale have limited small countries' ability to produce their own inputs). Second, it creates a certain self-sufficiency and improves balance of payments. Third, it could be done in either the public or local private sectors, as competition from the TNCs would be limited.

Agroindustry and Technical Transfer

Patterns in Latin America

An important form of private R&D and technology transfer in Latin American agriculture comes through the demand for product and production contracting practices of many agroindustrial or shipping firms (hereafter, "agroindustry" refers to any firm directly involved in organizing agricultural supply). These agroindustrial complexes have been extensively studied in Latin America (Arroyo 1981; Vigorito and Suárez 1981). Here we merely state some general propositions and consider a case study of technology transfer and R&D in Mexico.

First, what the agroindustrial firm does with regard to technology depends significantly on the land tenure structure. Dealing with large numbers of small peasant producers may be a disincentive to certain types of technology transfer because of the transaction and credit costs.

This is clearly evident in various transnational corporation (TNC) strategies in the acquisition of milk for processing in Latin America. At times, the firms have located production in remote regions where peasant producers have few alternatives, as in cases in Brazil, Peru, and Mexico (Frederiq 1981; Lajo 1981; Quintar 1983). Technological change is minimal, which gives rise to a conception of agroindustry as draining the surplus from a largely stagnant, functional peasantry. At other times the firms contract with large producers. A study of Nestle's milk plants in Colombia demonstrated a consistent effort to deal with large producers and to introduce better breeds, sanitation, new equipment, and feeds in trying to develop a higher quality supply base (Reyes Posada 1981). This type of arrangement creates a notion of agroindustry as a dynamic force driving the adoption of new technologies.

While there are scattered instances of the first type of arrangement in Latin America (many of which are under state control), it is now clear that, in general, agroindustries, especially the TNCs, are a dynamic capitalist force actively transferring technology and substituting for imperfect credit, input, and extension markets. The extent to which they are substitutes depends on the completeness of these markets. The questions that remain are "what technology do they transfer?" and "to whom do they transfer this technology?"

A second, and very broad, conditioning factor is the nature of the product industry involved. Different crops have varied levels of technological development arguing for more or less vertical integration or economies of scale. The industrial organization of the industry is also important: all TNCs or national firms; competition or oligopoly; large firms or small; local markets or exports. Finally, the relations between agriculture and industry are conditioned by the particular set of state policies, infrastructure, and political relations encountered in any one country.

Thus, the social and technical relations of local agriculture, conditioned by state policies, combine with the social and technical relations of the industry to determine the particular process of technology transfer. A brief case study will serve to exemplify this process.

The Mexican Frozen Vegetable and Strawberry Industries

The Mexican frozen vegetable and strawberry industries are concentrated in an area of central Mexico known as the Bajio. This is an extraordinarily fertile set of mountain valleys which have long been an important grain producing region, as well as a producer of fruits and vegetables since colonial times and, in this century, for the nearby population centers of Mexico City and Guadalajara. The Bajio is an area with a diverse agrarian structure.

Starting about 1950, a number of strawberry freezing plants were set up in the Bajio, mostly owned by entrepreneurial U.S. capital. These plants were followed in the late 1950s and early 1960s by a series of TNC fruit and vegetable canneries who chose the region for its population proximity, as they were locating plants to serve the local market under import substitution policies. These canners (Campbells, Del Monte, Heinz, Gerber, etc.) contracted with large farmers, introduced new crops, and delivered input packages (seed, chemicals, and some machinery) to contracted growers (Rama and Vigorito 1979). Although there were constant battles over the prices paid, these contracts were generally beneficial to the large growers and aided in a process of rapid capital accumulation.

Frozen vegetables

In 1967, Birdseye located a frozen vegetable plant in this region looking to export to the United States; it began to contract with the same strata of growers, again providing credit, technology, and technical assistance where required. In the mid-1970s, one family of the largest growers set up their own frozen vegetable plant and began to produce under contract both for Birdseye and other U.S. buyers. Their success was imitated by other growers in the late 1970s and early 1980s. In addition, the 1982 devaluations led to the entry of Green Giant and Campbells, and a rapidly growing number of plants vertically integrated to large growing operations, with some converting from strawberries.

The Mexican frozen vegetable industry, concentrating thus far on broccoli and cauliflower, has become somewhat of a sensation, competing successfully with California in the U.S. market. Mexico's share of the U.S. frozen broccoli market, for example, has risen from four percent in 1979 to 24 percent in 1986 (see Table 22). This example provides us with some interesting lessons on technology transfer, as it is increasingly appearing in the context of shifting competitive advantage and the development of "new exports" in Latin American agriculture.

First, the development of the capability to grow the crops on a scale and at a quality that allows Mexico to be an important competitor in the world market took a significant length of time: over 20 years after Del Monte began contracting and 15 years after Birdseye's entrance. The ability of Latin America to compete in new export markets may well depend on such cumulative developments.

Second, the TNCs consciously sought out the largest growers to cut transaction costs. However, over time these growers were able to accumulate sufficient capital, know-how, and knowledge of the markets to undertake their own export operations and construct their own plants. Virtually the entire industry, and much of its personnel, can be traced back to Birdseye. The prices offered by the TNCs were not sufficient given the grower's ability to act independently. Of course, since the TNCs dominate a large portion of the final market, a significant share of frozen product must still be sold to them by the integrated firms.

Third, this implies that the technical assistance program of the TNCs is actually a training and policing activity. There is a constant turnover of contracted growers so the TNCs must search out new potential suppliers and train them in the production of these crops. The TNCs implicitly charge new growers for this service (and all other services) by offering them lower prices for the raw product. For example, in the summer of 1986 the smallest growers who needed all services were being paid as low as 6.5 cents per pound for broccoli while the large integrated growers were selling excess raw product to the TNCs at up to 13 cents per pound.

Once the grower learns to produce the crop, visits from fieldmen are actually police actions to guarantee that he uses the proper chemicals. Since this is a relatively unskilled job, the fieldmen are often young, have little agronomic training, and are poorly paid. How much technical assistance is actually being offered to the growers is thus questionable. However, this group is no worse, and perhaps better, insofar as they work on only a few crops, than the majority of field workers for the Secretariate of Agriculture.

Fourth, the entire Mexican industry has relied on the TNCs to transfer technology, mainly from California. California produces approximately 1,000 million pounds of broccoli per year, while Mexico produces a little over one-tenth as much. Thus, the research effort in such crops is centered in California, both at the university and in the seed companies.

The TNCs substitute for a nonexistent research market. The Mexican government has concentrated on research for food crops rather than exports, so there is no public research

TABLE 22

Frozen Broccoli: Shares of the U. S. Market[a]

Year	California pack	Market share	Other U. S. producers	Market share	Imports from Mexico	Market share	Imports from Guatemala	Market share	Other imports	Total
	1 000 pounds	percent	1 000 pounds	percent	1 000 pounds	percent	1 000 pounds	percent	1 000 pounds	
1978	265 088	90.8	11 431	3.9	13 930	4.8	1 475	0.5	57	291 981
1979	298 618	95.1	0	0	12 213	4.2	2 149	0.7	88	314 069
1980	290 657	92.4	0	0	19 110	6.1	4 607	1.5	181	314 555
1981	288 700	86.3	18 055	5.4	22 542	6.7	5 161	1.5	120	334 578
1982	303 850	82.7	31 666	8.6	26 759	7.3	4 675	1.3	436	367 386
1983	260 359	81.6	24 999	7.8	27 747	8.7	3 238	1.0	2 566	318 909
1984	327 535	76.0	38 229	8.9	55 318	12.8	10 023	2.3	63	431 168
1985	309 836	71.4	46 970	10.8	63 376	14.6	12 666	2.9	1 105	433 953
1986	275 159	62.3	49 360	11.2	96 837	21.9	18 124	4.1	2 189	441 669

a Before U. S. exports, which are mainly to Canada; ignores carry-over stocks.

Sources: For California and United States, see American Frozen Food Institute (various years).

For imports, see U. S. Department of Commerce.

capability in such vegetables, and the seed companies had not seen the area as a significant broccoli market. However, the research undertaken by the TNCs is minimal adaptive work with few personnel. One firm ran an experimental program for years, only to have a new research director arrive and declare it all worthless and start again from scratch. Another firm brought in new personnel from the United States unfamiliar with the region and attempted to change fertilizing practices, with disastrous results.

As serious problems have arisen in production, the TNCs have increasingly had recourse to the University of California. One firm has a field station in Davis and another funded a young Mexican to study for a Master's Degree at Davis working on one of the more serious Mexican broccoli diseases. This benefits the Mexican industry by bringing in the latest varieties or research results, but it does not establish a Mexican research system capable of supporting such an industry in the long run unless such students are brought back and set up in a favorable research environment.

Mexican broccoli yields are not much worse than those in California, perhaps 70-80 percent, and, at the moment, broccoli can be produced in Mexico at about 40 percent of the cost in California (Moulcon and Runsten 1986). This is partly due to what BANAMEX estimated was a 37 percent underevaluation of the peso at the end of 1986. But, in the long run, Mexico's competitive advantage will depend on continued technological advances. Recently, as the industry has grown, the principal U.S. seed firms have expressed an interest in conducting research in Mexico on these vegetables, which would relieve the processing TNCs of this responsibility. However, it would not solve the public infrastructural deficit - the lack of University or extension personnel. It is also interesting to note how reluctant the large farmers are to fund joint research, perhaps because of a lack of history of cooperation with public agencies.

Fifth, the technology transferred to Mexico is only that of California. It was appropriate for the large growers, but as the TNCs work their way down into ever larger numbers of smaller growers, even several groups of **ejidatarios**, the technological package has to be modified. The TNCs are not well prepared to do this, and in general try to avoid it. However, in Guatemala, similar broccoli freezers, after poor results with large-scale farms, developed a system which allowed them to contract with large numbers of highland peasants. One firm alone reportedly has 2,500 peasants growing broccoli (Williams and Karen 1985). Such an agribusiness-peasant alliance is possible, but it requires significant time and R&D to make it work. The Guatemalan experience has not gone easily. But to the extent that agroindustry is offering the most profitable alternatives to agriculture, excluding the peasantry merely commits them to producing only wage foods at controlled prices, minimizing their opportunities to capture surplus.

Strawberries

If the Mexican frozen vegetables industry is a case of relatively successful technology transfer, the Mexican frozen strawberry industry offers us a contrasting result. The strawberry freezing industry expanded rapidly in Mexico in the 1960s and early 1970s and actually built about twice the capacity it was ever to use. The industry consisted of many small firms, as in the United States, all of whom sold principally through brokers into the U.S. market.

Mexico occupied a market niche by producing small Klondyke berries, but growers gave them up in the late 1960s when improved California varieties became available. This meant that Mexico competed directly with California in a market with stagnant demand.

While Mexican yields were always far below California yields, in the 1960s, with new varieties, Mexican yields grew at a rate similar to California's (see Figure 4 and Table 23). However, in the 1970s, Mexican yields actually declined while California yields continued to grow. This stagnation is fundamentally a failure of technology transfer and R&D in Mexico.

First, most of the largest growers in the area were never involved with strawberries. This limited the technological sophistication and access to capital of the industry. Strawberries are considerably more labor-intensive and difficult to grow than broccoli.

Second, there were no large corporations actively transferring technology and conducting R&D as in the frozen vegetable industry. U.S. capital was increasingly involved in Mexican strawberries only as an intermediary and had neither the ability nor the economic interest to transform production methods.

Third, the heavy clay soils of the region were never ideal for strawberries and, over time, disease problems arose. These were exacerbated as production was increasingly left to **ejidatarios** who had even fewer resources and insufficient land to rotate properly.

Fourth, government intervention was largely limited to output control, making prices uncompetitive, with only the most minimal research done to adapt varieties or solve disease problems.

FIGURE 4: STRAWBERRY YIELDS (Metric Tons/Hectare)

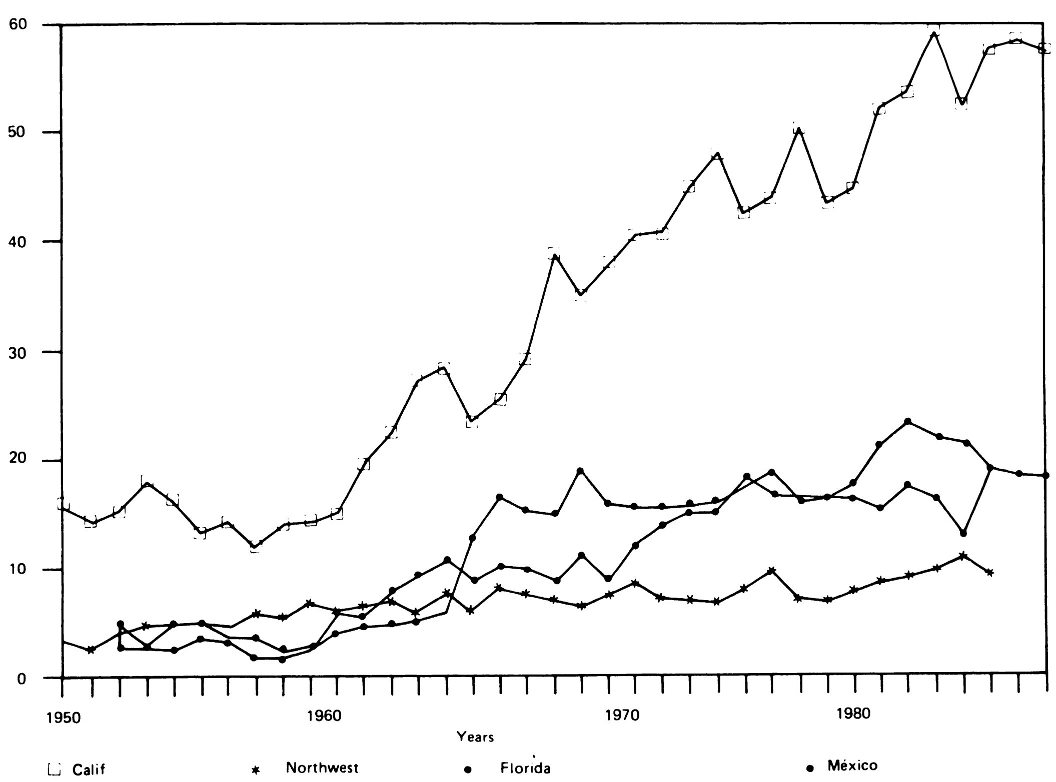


TABLE 23

Strawberries: Average Yields by Region

Period	California	Oregon and Washington	Percentage of California	Mexico	Percentage of California	Florida	Percentage of California
	1	2	3 = 2/1	4	5 = 3/1	6	7 = 6/1
	metric tons per hectare	metric tons per hectare	percent	metric tons per hectare	percent	metric tons per hectare	percent
1950-1954	16.0	4.0	25.0	4.3[a]	26.9	2.6	16.3
1955-1959	13.7	5.5	40.1	3.4	24.8	2.5	18.2
1960-1964	22.6	6.7	29.6	5.0	22.1	7.8	34.5
1965-1969	30.5	7.1	23.3	15.7	51.5	9.9	32.5
1970-1974	42.5	7.6	17.9	15.8	58.3	13.1	30.8
1975-1979	45.0	8.0	17.8	17.1	38.0	17.2	38.2
1980-1984	55.1	9.7	17.6	16.4	29.8	21.4	38.8
1985-1986	58.1	8.4	14.5	18.4	31.7	21.7	37.3

a 1952-1954.

Sources: For California, Oregon, Washington, and Florida, see U. S. Department of Agriculture (1985-86); for Mexico, see Union Nacional de Productores de Hortalizas and FAS reports.

TABLE 24

Frozen Strawberries: Average U. S. Market Shares[a]

Period	California pack	Percentage of total	Oregon and Washington	Percentage of total	Other U.S. producers	Percentage of total	Imports from Mexico	Percentage of total	Other imports	Percentage of total	Total
	metric tons										
1965-1969	34 138	26.6	50 610	39.4	9 002	7.0	32 974	25.7	1 720	1.3	128 444
1970-1974	38 640	30.5	37 292	29.4	4 512	3.6	43 721	34.5	2 609	2.1	126 774
1975-1979	60 625	46.9	24 526	19.0	2 922	2.3	36 558	29.3	4 624	3.6	129 255
1980-1984	77 542	55.8	33 442	24.1	3 357	2.4	21 228	15.3	3 440	2.5	139 009

a Before U. S. exports, juice-puree berries taken out after 1983; ignores carry-over stocks.

Sources: For the United States, see American Frozen Food Institute (various years).

For imports, see U. S. Department of Commerce.

Even with the tremendous devaluations of the 1980s, the industry is not important in the U.S. market because California introduced new yield-increasing technologies and outcompeted all other regions. Mexico's share of the U.S. frozen strawberry market fell from 35 percent in 1970-1974 to 15 percent in 1980-1984, while California's share rose from 30 percent to 56 percent over the same period (see Table 24). In part, California's gains in frozen berries are due to its virtual monopoly of the U.S. fresh strawberry market (which subsidizes frozen berry prices), but its advantage in both is due to the investment of large sums ($500,000 per year now) in research at the University of California by the strawberry growers' association and to large investments in the resultant technology at the farm level.

Mexico would appear to have a much greater comparative advantage in strawberries than in broccoli since strawberries require at least twice as much labor over a year (assuming three crops of broccoli per year). However, comparative advantages can only be exploited if technological, marketing, and other factors are equalized between regions, and the Mexican strawberry industry became seriously deficient in capital and technology. The TNCs served this function in the Mexican frozen vegetable industry, but it could also be undertaken through producer associations or state support, although alliances with firms in the developed countries may still be crucial to gain market access.

Producer Groups

A third aspect of agricultural research in the private sector is the growing investment in R&D by agricultural producers themselves. It has long been argued that producers were too small and numerous to fund such research; in any case, since the results were public goods, not enough of the benefits could be captured by those funding it - the "free rider" problem. Competition and rapid adoption of new technologies would assure that agricultural R&D funded by the public would flow back to society in the form of cheaper food.

However, the increasing size and specialization of farms in many areas along with new genetic techniques and the ability to patent them has altered this picture. New developments are particularly significant in many high value export commodities where competition among regions on a world scale has intensified as countries seek to increase and diversify exports.

Latin America has a history of commodity-specific research wholly or partly funded by producers in many traditional agricultural exports: coffee, bananas, or sugar in Colombia or Costa Rica; palm oil in Costa Rica; cocoa in Brazil; winter vegetables in northwest Mexico, and so forth. In many instances, the impetus for such research is defensive, for example, attempts to control pest and disease problems and thereby sustain production in a certain region. Similarly, much of the research funded by producer groups in California has been oriented more toward problem solving than toward attempting to gain a competitive advantage (Fujimoto and Kopper 1978).

However, there are notable exceptions. Piñeiro relates the story of Colombian sugar producers who formed a cartel to divide up an export quota to the United States and then formed a research center to develop a technological advantage over other potential producers in different regions of the country (Piñeiro 1985). The control of the quota made it possible to justify these expenditures.

The example of California strawberries discussed above is also instructive. Strawberry growers were able to capture significant resources in the University of California for plant breeding and other research by funding a continuous research program after about 1960. U.S. laws allow farmers to collude and form "marketing orders" for purposes of research, quality control, and advertising. The University eventually patented the new varieties and, as a public institution, licensed them around the world at nominal cost. California strawberry growers at first argued for low royalties since they had funded much of the research. However, as other regions of the United States and the world have become competitive with California by adopting these same varieties, California growers have begun to argue for much higher royalties on material licensed outside of the state.

Ten years before this joint research effort was begun, a private firm (Driscoll) hired away the University's strawberry breeder and has had an advantage because the breeding is done relative to California soils and climate; if they had to start anew they would probably pursue a completely private research effort in order to ensure control of the resultant technology.

We can see this same tendency in the strategies of the very largest California agricultural producers. For example, Sun World invested millions of dollars in research in Israel to develop patented tomatoes (Di Vine Ripe), peppers (Le Rouge Royale), and seedless watermelons. Superior farming similarly plans to develop patented, exclusive varieties (Schacht 1987). J.G. Boswell, the largest cotton producer, purchased its own biotechnology company (Kenney 1986).

The implications of such a trend for Latin America are that technology transfer in tradable commodities may be increasingly obstructed by producer groups who seek to gain regional control as a competitive advantage. That is, if producers rather than TNC input companies control technology, it may not be freely available except at a very high price.

This may even be true of commodities less traded in Latin America, for example poultry. Poultry breeding is controlled by a small number of firms who sell genetic material to all producing firms. This technology (the best breeds) is thus available worldwide at the same price. However, as broiler/turkey firms in the United States have become larger and more integrated, the temptation to turn breeding into a competitive element has grown. If this should occur, the market for the independent breeders might shrink to such a degree that they would close, leaving Latin America without a breeding source.

A possible conclusion is, therefore, that Latin America needs to undertake a larger and more diverse agricultural research effort not only to cut down on the cost of importing technology, but because, as research results become increasingly privatized, it may not always be possible to gain access to new technology in many specialized products.

6

THE BIOTECHNOLOGICAL REVOLUTION

Biotechnology will vastly increase the capacity to produce food in the world; how, where, and when this will occur is still largely speculative. Success has not come as quickly as originally projected. However, the enormous sums of money and scientific resources being invested in biotechnology in the industrialized countries almost guarantee that significant changes will occur before the end of the century.

In this section we summarize what is known about the development of the biotechnology industry as it applies to agriculture. Various possible consequences of new technologies are then considered, as are options for Latin American policies.

Definitions

Biotechnology is defined as the manipulation of living organisms for purposeful ends, either to alter their characteristics or to use them in some production process. In this broad sense, biotechnology has a long history, as it includes plant and animal breeding and fermentation processes. "But whereas the 'old' biotechnology depended largely on selection to obtain desired traits, the 'new' biotechnology uses an enhanced understanding of the molecular constitution of organisms to achieve directed alteration at the cellular and molecular levels" (Buttel, Kenney, and Kloppenburg, Jr. 1985).

The new biotechnology really addresses living organisms as machines, and assumes that by understanding how they are constructed, they can be altered or redesigned for distinct purposes. Of course, scientists do not completely understand genetics or microbiological processes, so biotechnology is a very empirical science in which progress is made by trial and error.

For this reason, the new biotechnology is often described as a set of techniques which have been developed to work on altering organisms. In agriculture, these techniques improve old practices, such as plant and animal breeding, and permit new practices, such as reproducing large amounts of identical cells in a laboratory.

There are at least 10 markets for biotechnological application in the context of food systems: agriculture, biologicals (enzymes, hormones, and therapeutic substances useful in animal agriculture, etc.), biomass, chemicals and pharmaceuticals (produced from bulk plant and animal material), energy (for example, alcohol), food processing, fuels, pesticides, and veterinary (Riggs 1985: 4).

The principal technologies identified as "biotechnologies" in the United States are cell-tissue culture, cell fusion-hybridoma production, recombinant DNA techniques, gene synthesis, separation, fermentation, enzymology, purification, large-scale purification, sequencing, and process monitoring control (Riggs 1985). Only cell fusion, recombinant DNA, and gene synthesis are "genetic engineering"; the rest can be termed bioprocessing technologies. Table 25 shows the relevance of these techniques to different food systems markets, and Tables 26 and 27 show their usage by U.S. biotechnology firms. Because we are principally concerned with agriculture here, we leave aside a detailed discussion of the bioprocessing techniques, although we discuss some possible consequences of such technology below.

New Biotechnology Techniques

One set of techniques revolves around gene transfer or DNA recombination. Genes from one organism are inserted into another. Genetic engineering then involves identifying which genes do what and managing the way these genes express themselves in the engineered organism (if indeed they can be made to express themselves.) "Selective expression" attempts to control the timing and location of genetic expression, and the transfer of plant genes to microbes (bacteria) allows experimentation with single genes.

A second set of techniques has evolved in the area of somatic cell genetics, the objective of which is the regeneration of plants from single cells (or groups of cells). The most well-known and widely practiced technique is tissue culture - the growing of plant and animal tissues *in vitro*. Tissue culture involves several techniques for the mass propagation (cloning) of cells and regeneration of plants. Such laboratory propagation is fast, has a low cost, and gives uniform results. It works well with vegetables, fruits, and trees, but not so far with grains.

A related technique is protoplast fusion, in which the cells of incompatible species are stripped of their walls and fused to form new hybrids. This allows wide crossing (among different species) and so holds the potential for nitrogen fixing in grains and similar results. However, the technique lacks specificity and transmits undesirable as well as desirable traits.

TABLE 25

Markets and Biotechnologies Relevant to Food Systems

	Markets[a]												
Technologies	**AG**	**BL**	**BM**	**CM**	**DG**	**EN**	**FP**	**FU**	**MN**	**PS**	**PH**	**TW**	**VT**
Bioprocessing		X	X	X		X	X	X	X	X	X	X	
Genetic engineering	X	X	X	X	X	X	X	X	X	X	X	X	X
Ecological engineering	X		X									X	

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

Source: Riggs (1985).

TABLE 26

Relative U.S. Industry Emphasis on Applied Technologies and Market Areas Sought[a]

Applied technology	Number of companies	Market areas sought	Number of companies
Cell/tissue culture	159	Biologicals	181
Hybridoma/cell fusion	141	Diagnostics	178
Recombinant DNA	132	Pharmaceuticals	140
Purification (lab scale)	127	Agriculture	110
Fermentation	120	Veterinary	106
Separation	110	Clinical tests	100
Enzymology	96	Chemicals	88
Purification (large scale)	90	Food processing	66
Synthesis	65	Pesticides	42
Sequencing	47	Biomass	34
		Energy	31
		Fuels	27
		Toxic waste processing	25
		Plastics	18
		Computer software	15
		Synthetics	14

a Indicated by the number of companies claiming development or use of each technology listed; most companies use more than one technology.

Source: Riggs (1985).

Fianlly, one interesting aspect of tissue culture is somoclonal variation in which genetic diversity can be encouraged among a growing mass of cells in the laboratory, and then these cells can be screened for desired traits. This avoids having to grow plants to find traits and vastly speeds up the breeding process (Lohr, Carter and Logan 1986).

There are, or course, other techniques such as monoclonal antibodies, which are being used to produce vaccines, or microbiological fermentation and enzymatic catalysis, which are being used to produce chemicals and foodstuffs synthetically, for biomass energy, and so forth. For agriculture, however, cell techniques and genetic engineering are the principal research technologies. We now turn to the main topics of agricultural biotechnology, or the application of these techniques.

TABLE 27

U. S. Companies Distributed by Technologies and Markets

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

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

Source: Riggs (1985).

Applied Agricultural Biotechnology

A first area of investigation is in creating disease and herbicide resistance in plants. This entails isolating and transferring genes within and across species. Plant breeders have been engaged in just such work for over 100 years without understanding the genetic basis of what they were doing.

Private firms are especially interested in chemical resistance which would allow them to package seeds and herbicides together. Some types of herbicide resistance are controlled by a single gene, making this a fruitful area of research. "The first successful artifically transplanted gene may be GlyphoTol, which protects crops implanted with it from the effects of the herbicide **Roundup** (and other glyphosate-based herbicides)" (Lohr, Carter, and Logan 1986: 41). One firm expects to market herbicide resistant tomatoes in 1988, cotton in 1989, soybeans in 1991, and corn in 1992.

In creating resistance to disease, one technique is to make the tissue disease free (virus free) through heating in the standard manner, but then cloning *in vitro* to propagate the plants. This has worked well with potatoes. Another approach is to innoculate the plants with vaccines; such vaccines are already on the market. Alternatively, biological fungicides can be created where one type of fungi consumes another; these, too, have been marketed.

A second area of research is in yield or quality improvement. For example, there are efforts to increase protein in grains, to increase solids in processing tomatoes, to breed larger fruits (as with California strawberries), or to make common oilseeds produce exotic oils, as with cocoa or jojoba. There is a general belief in California companies that yield improvement is not as useful as quality enhancement (Riggs 1985). In this sense, research is biased toward U.S. producers who are already swamped with overproduction and may not produce the yield increases which poorer countries could use.

Biotechnological techniques enhance such common aspects of breeding programs as haploidy, somoclonal variation, and mutant isolation. In other words, biotechnology expands and speeds up the normal process of trait isolation and transfer. In that sense, research is still limited by what exists in nature: if plants do not exhibit desired traits, how can one uncover the genetic basis of such traits?

A third research topic is growth enhancement. Nitrogen fixation, improved photosynthesis, and hormonal actions are major areas of concentration. However, all are difficult subjects and require significant basic research. For example, at least 17 genes have been identified as having to do with nitrogen fixation (Lakoff 1984). Thus, earlier predictions of nitrogen fixing in grains have been pushed back at least 10 years. A much better understanding of the interrelationships among genes will be required before this is solved, a problem common to many areas of biotechnology.

A fourth, related, and more accessible research area is environmental tolerance: creating resistance to drought, heat, cold, salt, or toxics. The choice here, as above with resistance to disease, is in either changing the plant or applying a product. For example, **Frostban**, which is really altered bacteria stripped of their frost-inducing trait, could solve the problems of many regions which suffer occasional freezes. On the other hand, salt tolerance has been bred into a number of grains in the U.S. Midwest. All of these qualities offer immediate economic returns to farmers and are hence a major area of corporate research.

A fifth broad area of investigation is crop pest control. Here there are four basic choices: genetically alter plants to improve their pest resistance; genetically alter pests; improve the effects of pesticides through better understanding of how chemicals affect pests; or pursue biological control of pests with microbial pesticides and fungi. A considerable amount of work has been done in all of these areas; biotechnology just improves the research techniques. (The preceeding two sections were derived in great part from Lohr, Carter and Logan 1986).

Biotechnological Products

There are a number of important products of biotechnology that are already available, or will be shortly, that we can use to consider some of the problems and opportunities which biotechnology presents for Latin American agriculture.

A vaccine for foot and mouth disease in cattle, a product of recombinant DNA technology and developed by two U.S. biotechnology companies, already exists and is being tested in Latin America (Buttel, Kenney, and Kloppenburg, Jr. 1985). This would make possible a greatly increased cattle export sector in some countries, with varying effects. It may be a definite boon to Argentina, but where extensive cattle ranching is in competition with peasant agriculture or forests, improvements in animal raising should be combined with efforts to intensify the activity. Biotechnology provides the opportunity to utilize crop waste and other biomass for animal feed combined, perhaps, with bioindustrially generated protein. Thus, a strategy could be devised to avoid negative social effects and resolve the contradiction between feed production and food production evident in a number of Latin American countries (Luiselli 1986).

Another biotechnology product which is about to be introduced is bovine growth hormone (BGH,) which will raise the milk productivity of dairy cows. Some rough calculations with FAO data give us an idea of the potential importance of this to Latin America. If we assume that milk product exports of Latin America stay within the region and subtract them from imports, then net imports should be the amount entering from outside. If these are converted to whole milk equivalents, then, as shown in Table 28, Latin American imports of embodied milk averaged 3.1 million metric tons in 1970-1974 and 4.3 million metric tons in 1980-1984. However, milk production in the region rose from 25.3 million metric tons in 1970-1974 to 34.5 million metric tons in 1980-1984. Thus, imports as a percentage of apparent consumption were stable at about 11 percent in both periods.

Now, the Office of Technology Assessment in the United States has estimated that BGH will raise milk production per cow about 25 percent with additional feed. Thus, if BGH were given to only half the (average) milk cows in Latin America, with extra feed, and they achieved the predicted increased production (i.e., were improved breeds), this would provide an additional 4.3 million metric tons of milk per year, or exactly the current deficit[1]. However, other studies have demonstrated that BGH raises milk per cow 10 percent with no additional feed (Buttel, Kenney, and Kloppenburg, Jr. 1985), so other options for diffusion are possible.

Therefore, depending on its cost, a technology that promises to cause serious surplus problems in the United States and Europe could be a boon to Latin America, if properly managed. This technology exists and will soon be marketed. It is a compelling reason why coherent policies for technology transfer in this area need more analysis. Will peasant milk producers be able to adopt it? Who will produce and market it in Latin America? Are patent laws sufficient in all countries to guarantee that it will be promptly available throughout the region?

A third example of the effects of biotechnology is the much-discussed use of enzymatic bioprocesses to create high fructose corn syrup (HFCS) and aspartame in the United States (Buttel, Kenney, and Kloppenburg, Jr. 1985; Arroyo 1986; Luiselli 1986; Gonzalez and Quintero 1985), which have now claimed about 65 percent of the U.S. sweetener market. Derived from a technology invented by the Japanese in the late 1960s, HFCS has been massively adopted in the United States because of wide price swings in the world sugar market and the effects of U.S. sugar price supports (Leu, Schmitz, and Knutson, forthcoming).

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1 This asumes, simplistically, that the deficit is distributed equally over the region and that specific milk product mixes are unimportant.

TABLE 28

Latin America: Net Imports of Milk and Milk Products[a]

	Average			
	1970-1974		1980-1984	
Product	Actual	Whole milk equivalent	Actual	Whole milk equivalent
	metric tons			
Fresh milk	6 008	6 000	19 677	19 677
Preserved and concentrated	0	0	10 773	32 319
Dry milk	240 727	1 829 525	334 630	2 543 188
Condensed and evaporated	93 003	204 607	109 568	241 050
Butter[b]	45 625	962 688	56 729	1 196 982
Cheese	14 546	145 460	25 546	255 460
Total				
Net imports		3 148 288		4 288 676
Whole fresh cow milk production		25 261 000		34 531 000

a Net imports = imports - exports (which assumes Latin American exports stay within the region).

b Conversion factor apparently does not take into account by-products of butter production and so overstates total milk required. This would lower the estimate of milk deficit.

Sources: United Nations – FAO, **Production Yearbooks** and **Trade Yearbooks**; conversion factor from U.S. Department of Agriculture (1985-86).

World sugar prices rose from 8 to 9 cents per pount to about 29 cents in 1974 and rose again from 9 to 10 cents to about 30 cents in 1980. Also, the United States supports domestic sugar prices at over 20 cents per pound. Production costs of HFCS are estimated to be about 12 cents. As a result, rapid substitution of HFCS has occurred since the mid-1970s, so that the U.S. consumption of imported sugar fell from 2.6 million tons to an expected 1.1 million tons in 1987. Thus, where imports accounted for 50 percent of the U.S. market, they now hold only about 25 percent (Leu, Schmitz, and Knutson, forthcoming).

World sugar prices have been depressed as a result, recently at 4 to 5 cents per pound. This, of course, has had serious negative effects on exports and balance of payments of a number of smaller countries in Latin America and the Caribbean.

It is also considered likely that similar substitutes will be developed for coffee, cacao, and many spices (Arroyo 1981; Gonzalez and Quintero 1985). This is just the culmination of a process of the substitution of synthetics for natural products which has occurred since World War II. Important exports of developing countries, such as cotton, wool, jute, sisal, rubber, and vanilla, were affected earlier. The demand for the natural product does not disappear, but it is confined to a smaller market segment where quality is often important. Countries currently engaged in the large-scale export of potentially threatened commodities might consider differentiating their product in anticipation of competing in a more limited, luxury market.

A different technology with similar results comes from the direct application of cell tissue culture to the extraction of chemicals from cultured plants. This allows the transfer of agricultural activities into the factory and the elimination of plant growing altogether. "In addition to high-value/ low-volume chemicals, corporate research in both Japan and England is underway to grow huge quantities of tobacco cells to replace or supplement leaf tobacco in tobacco products. The areas that would appear most promising economically in the near future include naturally occuring drugs, flavors, fragrances, dyestuffs, and crop protection chemicals" (Buttel, Kenney, and Kloppenburg, Jr. 1985: 44).

A similar situation may develop in the production of protein for animal feed. Single cell protein factories have been set up in Britain and the Soviet Union, and, though presently uneconomic, costs are expected to fall below soybean production costs (Buttel, Kenney, and Kloppenburg, Jr. 1985: 48). This production may displace some soybeans from the United States, Brazil, and Argentina. In addition, it may be possible to fuel such production from plant waste, which promises to greatly reduce animal feeding costs in developing countries.

Such developments mean that the international division of labor in agriculture will be changed relatively quickly after the introduction of biotechnologies. There has been a growing tendency for 30 years for the United States and Europe to import more competitive food items (i.e., foods that can be grown in the north) and proportionately fewer tropical products from the developing countries. However, such diversification of agricultural exports is most advanced in the larger countries such as Brazil and Mexico, whereas many small countries are still dependent on traditional exports. Declining demand for these products will make more land available either for food or for nontraditional exports. This provides an opportunity which must be planned for.

A fourth new product mentioned above is "ice-minus" or **Frostban,** a bacterial application that prevents frost from forming on plants. The first field testing of the product has just occurred in California in April-May, 1987. It was about 60 percent successful and the company expects to market it in 1990 (San Francisco Examiner, June 9, 1987). Again, the implications are mainly geographic in terms of world-cropping patterns, but they would seem to work against long-distance shippers and favor more localized production, as well as benefiting regions farther from the equator.

Finally, in the short-run, many of the early products will be seed-chemical packages like the herbicide-resistant crops. Such developments occur first because much of the research in the United States is being financed by the large chemical/seed companies and because the smaller start-up companies have to produce saleable products to survive (Riggs 1985; Kenney 1986). Such packages will probably raise farm input costs where they are adopted.

This last example suggests that, in Latin America, a new wave of inputs will be sold first through the normal TNC marketing channels to commercial producers. That is, whoever benefited from earlier chemical input developments will benefit first from biotechnology. Biotechnology will be introduced **on top of** the existing production and marketing structure (Buttel, Kenney, and Kloppenburg, Jr. 1985). In the specific case of herbicides, Latin America is not a very large producer, so it is likely that imports to the commercial sector will increase if this technology is clearly superior and, in addition, more hand-weeding labor will be displaced.

Industrial Organization of Biotechnology and Research

Until the 1970s, agricultural/animal production inputs were for the most part marketed by distinct firms in each product area: seeds, chemicals, pharmaceuticals, machinery, petroleum. However, a combination of factors has given rise to a restructuring of these input industries and the manner in which research is conducted which will have implications for the development and transfer of biotechnology to Latin America in agriculture.

First, the passage of "Plant Breeders' Rights" legislation in Europe in the early 1960s and the "Plant Variety Protection Act" in the United States in 1970 led to the acquisition of a large number of seed companies by mainly agrichemical corporations (Mooney 1979). It now seems likely that virtually all of the seed companies will become centerpieces of biotechnology TNCs.

Second, the profitability of the chemical industry has declined significantly since the 1960s, exacerbated in the mid-1970s by rising energy costs and environmental controls. Also the TNC oil companies, in joint ventures with LDC oil producers, are entering the bulk petro-chemicals industry. This has led the chemical companies to diversify and concentrate on specialty end-products (Kenney 1986).

Third, the first cloning of a gene in 1973 and the first successful expression of a cloned gene transferred to a host bacterial cell in 1974 led to rapid advances in biotechnology techniques and the formation of genetic engineering companies starting with Genetech in 1976 (Riggs 1985; Kloppenburg, Jr. and Otero 1985). It was estimated in 1984 that there are now 300 biotechnology firms in the United States, some 150 Japanese corporations participating or planning to enter, drawing on foreign research, and over 100 firms in other countries (Riggs 1985; Lohr, Carter, and Logan 1986).

Fourth, the few dozen large pharmaceutical, oil, and chemical companies, seeing the tremendous growth of the industry, began in the late 1970s to finance contract biotechnology research in the universities (Table 29) and in smaller start-up firms (Table 30 and 31) and to invest relatively large sums in in-house R&D units (Table 32).

Fifth, the U.S. Supreme Court decision **Diamond vs. Chakrabarty** in 1980 allowed the patenting of novel living organisms and genetic sequences spliced into new organisms (Kenney 1986). Thus, the Supreme Court signalled that this new technology was open to economic investment and private appropriation. Without patent protection, biotechnology R&D would probably be more secretive within corporations and there would have been less effect on university research, but it is doubtful that the essentially private nature of biotechnology research would be drastically different (Kenney 1986).

As this biotechnology industry has developed with respect to agriculture, it has become apparent that the techniques cross over chemical, seed, nutrient, and pharmaceutical lines, creating synergies in research, prompting greater merger activity (Buttel, Kenney, and Kloppenburg, Jr. 1985; Kenney 1986). Monsanto is an example of the type of company which emerges as a dominant actor in agricultural biotechnology (Table 33). With the exception of agricultural machinery, all agricultural inputs are brought together in one industry which has prompted speculation that technology will increasingly be developed in packages of inputs that interact with one another. Since all of these products will be patentable, it seems likely that higher yields or lower risk will come with increased working capital demands, at least in the

TABLE 29

Summary of Large University-Industry Research Grants in Chronological Order[a]

Year[b]	University	Company	Amount	Duration of years	Investigator	Area of research
			million dollars			
1974	Harvard Medical School	Monsanto	23.5	12	M. Folkman B. Vallee	Cancer tumors
1980	Massachusetts Institute of Technology	EXXON	8.0	10	J. Longwell P. Sarofim	Combustion
1981	Massachusetts General Hospital	Hoechst	70.0	10	H. Goodman	Genetics
1981	Harvard Medical School	Du Pont	6.0	5	P. Leder	Genetics
1981	University of California, Davis	Allied Corp.	2.5	3	R. Valentine	Nitrogen fixation
1981	Scripps Clinic and Research Foundation	Johnson & Johnson	30.0	b	c	Synthetic vaccines
1981	Washington University	Mallinkrodt	3.8	5	J. Davie	Hybridomas
1981	Yale University	Celanese	1.1	3	N. Ornston	Enzymes
1982	Johns Hopkins University	Johnson & Johnson	1.0			Biology
1982	Rockefeller University	Monsanto	4.0	5	N. Chua	Photosynthesis
1982	Washington University	Monsanto	23.5	5		Biomedical
1982	Massachusetts Institute of Technology	W. R. Grace	8.0	5	P. Thilly	Amino acids
1982	Yale	Bristol-Myers	3.0	5		Anticancer drugs
1982	Cold Spring Harbor	EXXON	7.5	5		Molecular genetics
1983	University of Rochester	Kodak	0.45			DNA
1983	Medical University, South Carolina	Chugai	0.5	3	A. Strelkauskas	Monoclonal antibodies
1983	University of Illinois	Sohio	2.0	5		Plant molecular genetics
1983	Columbia University	Bristol-Myers	2.3	6	A. Efstratiadis	Gene structure

a An attempt to be exhaustive has been made, but, because of the secretive nature of many universities, these data are tentative and incomplete.

b In all years a number of large grants have been made by Agrigenetics to various researchers at a number of universities.

c Blanks indicate no data available.

Source: Kenney (1986).

TABLE 30

Genentech's Research Contracts by Product with Multinational Corporations, 1982

Product	Multinational corporation	Company's nationality	Type of contract	Cost
Insulin	Lilly	United States	Exclusive (world)	Royalties
Human growth hormone	Kabi-Vitrum	Sweden	Exclusive (except U.S.)	Royalties
Human interferon (α)	Hoffmann-La Roche	Switzerland	Exclusive (world)	Royalties, right to supply
Human interferon (γ)	Daiichi Seiyaku Toray Industries	Japan Japan	Exclusive (except U.S.)	Royalties, right to supply
Bovine growth hormone	Monsanto	United States	Exclusive (world)	Royalties
Tissue plasminogen	Mitsubishi Kyowa Hakko	Japan Japan	Exclusive (Japan)	Royalties
Human serum albumin	Mitsubishi	Japan	Exclusive (Japan)	Royalties
Bovine interferon	Granada	United States	Exclusive	$ 20 million

Source: Kenney (1986).

short run, and that their adoption in Latin America will mean greater patent and licensing royalties to the industrialized countries. However, we can expect that much production of biotechnology products will occur in Latin America and other developing areas, although this will be unevenly concentrated in the larger countries (Riggs 1985).

One important aspect of the development of the biotechnology industry has been the close relationship developed between public and private actors. Joint R&D among universities, governments, and private firms is the rule as countries compete against one another for dominance in the industry. Some governments have created and financed biotechnology companies for specific purposes: Celltech in England, Transgen in France, Allelix in Canada [Programa de las Naciones Unidas en Desarrollo (PNUD) 1986]. And university research has become increasingly financed by private corporations with an extensive concern for patenting that implies that results are no longer as freely available as in the past (Kenney 1986).

In this context, the situation in Latin America is difficult for autonomous development of a biotechnology industry. First, there is a lack of a history of cooperation between universities and industry in Latin America. This has many causes, but it is changing very slowly, and there is still great suspicion within the universities of the private sector (Waissbluth, Cadena, and Solleiro 1985). Second, Latin American private firms do not have a history of spending much on R&D. For example, in Mexico less than 15 percent of R&D is done by industry as opposed to 50 percent and above in OECD countries. To a certain extent, this is due to the dominance of TNCs, who do their research elsewhere, in many

TABLE 31

Selected Start-Up Companies with Multinational Partners and Various Contract Features

Start-up company	Multinational corporation	Nationality	Value	Duration of years	Board of directors	Equity
			million dollars			percent
Integrated Genetics	Silliker Laboratories	United States	a		No	
	Toyobo	Japan			No	
	Connaught Laboratories	Canada			No	
	Serono Laboratory	Netherlands			No	
Amgen	Abbot Laboratory	United States	19.0	5	Yes	11.9
	Tosco	United States			Yes	8.4
Genetic Systems	Syntex	United States	3.9	3	No	3.1
	Cutter Laboratory	Germany	1.6	3	No	
Hybritech	Johnson & Johnson	United States	2.1	4	No	
	Baxter-Travenol	United States	2.9		No	
	Teijin	Japan	7.5	3	No	
	Baker Instruments	United States				
	American Cyanamid	United States	1.9	3	No	
Genex	Allied Corp.	United States	16.5	5	No	
	AB Fortia	Sweden			No	
	Bristol-Myers	United States	2.5	3	No	
	Green Cross	Japan			No	
	Kabi-Vitrum	Sweden			No	
	Koppers	United States	2.5	3	Yes	29.0
	Schering AG	Germany		1.5	No	
	Yamanouchi	Japan			No	
Advanced Genetic Sciences	Rohm and Haas	United States	5.0	2	Yes	14.9
	Hilleshog	Sweden	1.9	2	Yes	14.9

a Blanks indicate no data available.

Source: Kenney (1986).

TABLE 32

In-House Corporate Life Science Research: Description and Location[a]

Company	Area of research	Location	Description
Monsanto	Biological sciences	Missouri	$ 185 million
Du Pont	Life sciences	Delaware	$ 85 million
Chevron	Agriculture	California	$ 38 million
Lilly	Biomedical	Indiana	$ 60 million
Ciba-Geigy	Agriculture	North Carolina	$ 7 million
Pfizer	Agriculture	Missouri	20 researchers
ARCO	Agriculture	California	15 scientists, 57 employees
Allied Corp.	Agriculture	New York	50 employees

a These data are accurate according to the best of currently available information.

Source: Kenney (1986).

research-intensive industries. However, there is a noticeable lack of experience in national firms with scaling-up research results into production activities (Waissbluth, Cadena, and Solleiro 1985). The transfer of technology from abroad has not created sufficient innovative capabilities.

How, then, will Latin American biotechnology firms compete with the TNCs? The simple answer is they cannot and probably should not try (Arroyo 1981). Instead, just as with many smaller companies in the industrialized countries, they will have to find market niches (perhaps small markets) they can occupy without competing head-on. There are doubtless many such opportunities, and they could be identified and assisted by government activity in this area. Without greater coordination between the public and private sector, however, the firms will have to look to research in the industrialized countries, and Latin America will forego the opportunity to gain private funds for research and to develop an indigenous innovation capability. This is already occurring with the only Mexican biotechnology firm (Otero 1987).

The future of existing national input companies in Latin America is much more unclear. To the extent the TNCs already control such input industries in many countries, or the local firms are merely distributors of TNC products as in small countries, the transition to biotechnology may not change much. However, independent or state seed, chemical, and fertilizer companies could be negatively affected. It is impossible to predict this, but certainly it argues for improved human resources in biotechnology which can be used to sustain competitiveness, whether within such firms or (as in the case of seeds) at the International Agricultural Research Centers.

TABLE 33

Monsanto–Anatomy of a Biotechnology Company

In-house investment

$ 185 million invested in biological sciences research center

Pharmaceutical companies

Purchased G. D. Searle Co. for $ 2.8 billion

Biotechnology companies (equity investments and important contracts)

Collagen–artificial bone powder
Biogen–tissue plasminogen activator
Genentech–bovine growth hormone
Genex–venture capital investment
Biotechnica International – *B. subtilis* protein expression

University contracts

Harvard University–biomedical research ($ 23 million)
Washington University–biomedical research ($ 23 million)
Rockefeller University–photosynthesis research ($ 4 million)
Oxford University–sugar chains ($ 1.5 million)

Seed company subsidiaries

Jacob Hartz
Hybritech Seed Co.
Monsanto Seed
Farmers Hybrid Co.

Fertilizer

Fifth largest U. S. producer of nitrogenous fertilizers

Pesticides

58 percent share of grass herbicides market in corn (1978)
Roundup–revenues of $ 500 million
Lasso–revenues of $ 200 million

Source: Kenney (1986).

Biotechnology in Latin America

In contrast to the situation in the United States where large corporations, universities, and significant government funding of biotechnology research have combined to create rapid progress in the field, Latin America is, for the most part, tremendously disadvantaged. Latin America has weak basic agromedical science - genetics, microbiology, molecular biology - and the universities of the region are generally not research institutions (Goldstein 1985). There is a shortage of trained personnel (Piñeiro 1985; Roca, Amezquita, and Villalobos 1986) and a "brain drain" to the north (Morales 1985). The fiscal crisis of the region has led to low levels of government funding for research. Finally, the chemical/pharmaceutical industry is composed mainly of TNC subsidiaries, and little research is done in the region (Goldstein 1985).

A recent survey of Latin American biotechnology research (Roca, Amezquita, and Villalobos 1986) found that only 40 percent of biotechnology investigators had postgraduate training, mainly in cellular biology. As a reflection of this, while 88 percent of institutions responding conducted research using cell tissue culture, molecular biology (recombinant DNA) was little developed (see Table 34). Tissue culture is done in relatively inexpensive laboratories; it has long been used to reproduce plants such as grapes; and it does not require understanding the genetic structure of organisms (Arroyo 1981). Thus far there are few successful applications of genetic engineering to agriculture and crop breeding (Plucknett *et al.* 1985), but it is just a matter of time before this deficiency becomes significant. Similarly, Latin American biotechnology research on animals was found to be limited to fertilization, embryo transplants, and some vaccine production with no genetic engineering work underway (Roca, Amezquita, and Villalobos 1986: 19.)

The lack of personnel working in basic sciences in Latin America is a serious problem because the most important aspect of biotechnology research is human capital. For example, TNCs do not take over many start-up biotechnology firms in the United States because they are afraid the scientists will leave, and that is really all they are buying. Instead, as discussed above, the TNCs subcontract research to the start-up companies or to university researchers (Kenney 1986).

In the Latin American survey, 82 institutions had 160 Ph.D.s working in biotechnology related fields, or about two Ph.D.s per center. Table 35 shows the average distribution of personnel by type of institution. When one considers that many of these Ph.D.s are probably administrators and perhaps teachers as well, it leaves few people to do research.

TABLE 34

Tecnologías Actuales: Uso de las Distintas Tecnologías en las Diferentes Areas de Investigación Tecnológica

Area de investigación biotecnológica	Tecnologías	Instituciones[a]	
		número	por ciento
Celular	Cultivo de tejidos: protoplastos, células, meristemos, anteras, ovarios y otros	72	88
Genética/Citogenética	Cariotipos, mapas genéticos, morfología cromosómica, herencia y otras	38	46
Bioquímica	Purificación y separación de proteínas y ADN biosíntesis de metabolitos	32	39
Nuclear	Mutagénesis, sondas marcadas	27	33
Inmunología	Anticuerpos monoclonales, pruebas inmunológicas, bioproducción de vacunas	23	28
Molecular	ADN recombinante, clonación de genes, transferencia, regulación y expresión génica	19	23

a Resultado de 82 Instituciones que contestaron el cuestionario.

Source: Roca, Amezquita, and Villalobos (1986).

TABLE 35

Latin American Biotechnology Researchers:
Average Number of Personnel per Institution by Type of Research Center
(82 Respondents)

Type of center	Ph.D.	M.C.	B.C.	Total personnel
Universidad	2.5	2.0	3.1	9.9
Inst. Nacional de Inv. Agrícolas	1.7	2.4	3.2	9.8
Inst. Nacional de Inv. no Agrícolas	1.7	1.0	6.0	11.3
Centro Internacional de Inv. Agrícolas	2.7	0.7	4.3	11.3
Inst. Internacional Regional	0.8	0.2	3.3	4.8
Inst. Mixta	0.8	1.0	1.8	4.2
Compañía Privada	1.9	1.1	3.1	13.4
Unweighted average	2.0	1.8	3.1	9.7

Source: Roca, Amezquita, and Villalobos (1986). Derived from Tables 2 and 9.

However, the situation is, of course, worse in many Latin American countries, as the distribution of researchers is skewed toward the larger countries like Brazil, Mexico, and Argentina. For example, of the 160 Ph.D.s, 20 were at the Instituto de Genetica in Brazil, and 62 (or 39 percent) were in just six institutions (7 percent) (Roca, Amezquita, and Villalobos 1986). Of the 14 universities offering Ph.D.s in biotechnology topics in the survey, 9 were in Brazil.

This survey also points up the low levels of funding in Latin America. Of the 82 institutions responding, only 33 percent had more than $100,000 in biotechnology infrastructure and only 27 percent had more than $50,000 in budget in 1986. Assuming the high end of the 1986 budget estimates reported, the total biotechnology-related budget for these 82 groups cannot total more than $2 million.

In contrast, by 1984 the private biotechnology industry in the United States had attracted more than $4 billion in investment, and Genentech, the leading genetic engineering firm, alone had a staff of 674 with 133 Ph.D.s and an annual R&D budget of over $20 million (Kenney 1986). Table 36 shows the quantity of personnel in a few biotechnology companies. Kenney reported the cost in the United States in 1980 of setting up laboratory space for a Ph.D. at $75,000-$150,000, and the annual support cost at $100,000-$125,000. Industry analysts estimate that the U.S. government will spend $2 billion this year on biotechnology-related research, and other sources in the United States will spend over $1 billion (**New York Times**, June 8, 1987).

These great disparities have prompted action by Latin American governments and international agencies to try to achieve a critical mass in biotechnology research, for fear that net balance of payments in food and energy will worsen if some self-sufficiency in biotechnology is not achieved (PNUD 1986). While it does appear that some research can be accomplished, it also appears that it will be uneven across Latin America.

TABLE 36

Annual Employee Populations of Selected Biotechnology Start-Ups, Doctoral Level, Nondoctoral, and Total

	1976	1977	1978	1979	1980	1981	1982	1983	1984
Cetus[a]									
Doctoral	13	14	21	31	43	62	82	77	97
Nondoctoral	107	106	142	168	230	398	398	450	516
Total	120	120	163	199	273	460	480	527	613
Genentech[b]									
Doctoral	–[c]	–	2	–	49	74	89	114	133
Nondoctoral	–	–	5	–	117	244	342	429	541
Total	–	–	7	56	166	318	431	543	674
Genex									
Doctoral	–	1	1	6	21	41	48	48	48
Nondoctoral	–	0	2	13	49	150	153	171	216
Total	–	1	3	19	70	191	201	219	264
Biogen[d]									
Doctoral	e		1	–	–	–	79	90	87
Nondoctoral			2	–	–	–	172	241	289
Total			3	3	41	154	251	331	376
Molecular genetics									
Doctoral			–	1	5	23	25	24	26
Nondoctoral			–	2	9	33	42	77	98
Total			–	3	14	56	67	101	124

a Cetus was already an operating company.

b Genentech was unable to provide personnel populations for its earliest years. Full-time employees that Genentech had in H. Boyer's laboratory at the University of California, San Francisco, were omitted.

c Dashes indicate no data available.

d Biogen was unable to provide as much information as other companies.

e Blanks indicate companies did not exist.

Source: Kenney (1986).

The only two Latin American countries which appear on a list of countries with actual national biotechnology plans and programs are Brazil and Argentina 9PNUD 1986), Brazil's program having started in 1986 (Pinheiro 1985). In organizing a United Nations cooperative effort, the supporting countries were: Argentina, Brazil, Costa Rica, Cuba, Chile, Mexico, and Venezuela (Grau 1985). The only Latin American countries listed with private biotechnology companies are Argentina, Brazil, Chile, and Mexico (Pinheiro 1985; Otero 1987; PNUD 1986).

Pilot bioprocessing plants reported in operation in the region were in Argentina, Brazil, Cuba, and Mexico (PNUD 1986). Tables 37 and 38 show the numerous centers and topics of biotechnology research in Brazil, which is in great contrast to most other countries. Apparently, even TNCs such as Monsanto are conducting biotechnology research in Brazil (Pinheiro 1985).

Thus, the disparity of resources and research on a world scale is mirrored in Latin America. Some countries will have success with biotechnology programs, but most will not. Most countries of Latin America will depend on technology transfers, perhaps mainly by TNCs and, from this standpoint, not nearly enough consideration is being given to the management of this transfer process as opposed to efforts to create scattered self-sufficiency projects.

Apart from the national programs, the main organization effort in the region appears to be coming from the United Nations agencies. A **Red Latinoamericana de Centros de Biotecnologia** was first proposed in the late 1970s. The United Nations Development Program (UNDP) funded preliminary organizational work in 1983, a conference was held in La

TABLE 37

Alguns Órgãos, Programas e Empresas Vinculados à Aplicação da Biotecnologia na Area Agrícola

Instituições	Objetivos
EMBRAPA	Fixação de nitrogênio em leguminosas e gramíneas, com a utilização de bactérias
Programa UNEP/UNESCO/ICRO	Fixação biológica de nitrogênio em leguminosas (IPAGRO/RS)
Instituto de Zootecnia (Secretaria de Agricultura/SP)	Fixação de nitrogênio
ESALQ/CENA	Aplicação de energia nuclear na criação de novas espécies vegetais
	Preservação de alimentos; controle de pragas
PLANALSUCAR/IAA	Novas variedades de cana-de-acúçar
EMBRAPA	Novas matérias-primas para produção de energia (mandioca e sorgo)
ESALQ/USP	Utilização de leveduras secas na produção de ração animal
CENARGEN/EMBRAPA	Qualidade e armazenamento de sementes (engenharia genética)
Monsanto do Brasil	Reguladores de crescimento para a cana-de-açúcar (aumentar o teor de sacarose)
	Produção de insumos agrícolas
BIOPLANTA	Biotecnologia genética
AGROCERES	Produtos genéticos para avicultura e suinocultura e produção de sementes
Fundação BRADESCO	Inseminação artificial
Volkswagen do Brasil	Inseminação artificial e melhoramento do rebanho bovino
Grupo Perdigão	Novas linhagens na avicultura

Source: Pinheiro (1985).

TABLE 38

Centros Brasileiros Com Programa de Pesquisa em Biotecnologia Vegetal

Centro	Atividade de Pesquisa
Escola Superior de Agricultura Luiz de Queiroz USP-Piracicaba (Depts. de Quimica e de Silvicultura)	Genética Clássica e Cultura de Tecidos Vegetais (ornamentos, feijão, cana, eucalipto); Melhoramento Vegetal.
Instituto Agronomico de Campinas	Genética Clássica e Cultura de Tecidos; Limpeza de Virus e Melhoramento de Várias Cultivares Comerciais.
UNICAMP/CAMPINAS-Dept. Genética	Cultura de Tecidos (tomate).
EMBRAPA/PASSO FUNDO	Cultura de Tecidos p/Melhoramento de Trigo e Triticale.
CNPFT-EMBRAPA/PELOTAS	Laboratório para Limpeza de Virus e Melhoramento por Cultura de Tecidos.
PLANALSUCAR/IAA-PIRACICABA	Genética de Cana, Cultura de Tecidos.
Instituto Biociencias/USP-Deptº. Botânica-SP	Genética de Tomate, Cultura de Tecidos.
Instituto Biologia/UFRJ	Cultura de Tecidos e Melhoramento de Arroz e Tomate.
Núcleo de Pesquisa de Produtos Naturais	Fotoquímica e Extrativismo de Cultura de Tecidos.
Universidade Fed. Vicosa-VICOSA/MG	Cultura de Tecidos e Melhoramento de Citrus.
EPAMIG/MG	Cultura de Tecidos e Melhoramento de Cultivares Comerciais.
CEPLAC/BA	Cultura de Tecidos de Cacau.
Universidade Fed. Ceará	Cultura de Tecidos de Jojoba e outros.
EMBRAPA/CENARGEN e CNPH-BRASILIA	Cultura de Tecidos e Melhoramento de Cultivares Comerciais; Engenharia Genética de Vegetais.
PESAGRO-RIO/UPBS-EMBRAPA	Genética Clássica e Molecular da Associação de Plantas com Bactérias Fixadoras de Nitrogênio.
INST. BIOFÍSICA/UFRJ	Fisiologia e Ultra-Estrutura Vegetal; Microscopia Eletrônica.

Source: Pinheiro (1985).

Plata in 1984, another in Havana in 1986, and now a joint UNDP/UNESCO/UNIDO project will be funded with about $5 million over five years (PNUD 1986; Grau 1985). Participating countries will provide infrastructure and about 25 percent of costs. The UNESCO educational and organizational aspect of the project will be based in La Plata and the UNIDO R&D subprogram will be based in Mexico City (PNUD 1986).

In the 1984 La Plata conference, a long list of desirable research topics was drawn up, including work on nitrogen fixation. However, after reviewing actual research underway, it was determined that the first areas of effort would be: Health - diagnostic systems (such as virus detection); Agriculture - micro-propagation of vegetables (such as multiplication of virus-free root stock; and Industry - utilization of enzymes for industrial processes (PNUD 1986). Thus, from ambitious projects such as nitrogen fixation, which will require considerable basic research, a more pragmatic assessment of resources acknowledges that agricultural biotechnology research in Latin America is mainly cell-tissue culture as discussed above.

Policy Areas

While there are many dilemmas surrounding the new biotechnology and the appropriate focus and policies to deal with it in Latin America, here we treat three issues: biological pest control, peasants, and patents.

Pest Control

We might call the period since World War II the "chemical age" of agriculture, as the liberal application of chemical fertilizers and pest and disease control chemicals led to significant yield increases and decreased risk, an input package developed in the United States and Europe and later transferred to Latin America. However, the end of this chemical agriculture is now clearly in sight.

On the one hand, the widespread use of chemicals creates its own contradictions in terms of pest resistance: chemicals must be changed as pests adapt and, at times, more serious problems arise from the destruction of predators. As estimated 428 species of anthropods, of which 268 are agricultural pests (insects, mites, and ticks) have become resistant to one or more pesticides worldwide. Resistance to herbicides has also occurred in 150 plant pathogens (fungi and bacteria) and about 50 weeds. Half of the 428 pest species are resistant to two or more of the five major insecticide groups, and at least 17 have adapted to all five (Croft 1986).

On the other hand, many chemicals created health risks, damaged wildlife and the environment, and finally leached into drinking water supplies in such intensive-use areas as California. This has brought ever-increasing regulation in the developed countries, including severe new restrictions in California in the past year. At the same time, U.S. regulations in the 1970s made it increasingly difficult to register new agricultural chemicals. The cost to develop new pesticides rose dramatically, both because of regulations and because of the need to review ever more chemicals to find an efficacious one (see Table 39).

The result is that fewer agricultural chemicals are coming on line and a major shift to biological forms of pest control is now in the offing. Chemical companies were previously not interested in nonchemical forms of pest control as they were not saleable products, and research in the United States on integrated pest management (IPM) was generally confined to public institutions. But biotechnology presents the possibility of creating biological products (fungi, nematodes, bacteria, etc.) which can be packaged and sold. As the chemical companies have bought up seed firms and become heavy investors in biotechnology, they have positioned themselves to substitute biological products for chemicals as the chemicals are increasingly restricted. Also a service industry of IPM advisors has come into being in California, a type of precondition to a transition away from chemicals.

TABLE 39

Annual Pesticide Research and Development Costs

Item	Unit	Annually		
		1967-1970	1974-1975	1977-1978
New products registered	Number	10	9	2
Compounds screened	Number	6 500	78 000	84 000
Elapsed time from discovery to full registration	Month	68	97	110
Total research and development costs	Million dollars	61	238	290

Source: Eichers (1980).

What implications does this have for Latin America? First of all, for products traded in the world market, there is a trend already underway to require that they be produced without chemicals banned in the importing country, whether residues exist or not. Thus, as more agricultural chemicals are restricted in the industrialized countries, Latin American exporters will have to adopt alternative technologies. This is a particularly serious problem in fruits and vegetables and other "new" agricultural exports of Latin America.

For products for internal consumption, it may appear possible to continue with "old" chemical technology, but it will be increasingly difficult to sustain this type of agriculture. As biotechnological applications develop with considerably altered seeds and seed-chemical interactions, companies may give up research on conventional agricultural chemicals. Thus, the chemical options available will decrease, and overuse of remaining chemicals will render them useless. As these problems worsen in an area, there will be no research to provide "old" technology (because everyone was dependent on the TNCs for chemical research), and growers will either have to adopt biotechnological developments, go to more organic farming methods, or give up the crop.

Thus, it appears important for Latin American countries to develop capabilities in IPM and biological control methods for several reasons. First, they may be requisites for export markets. Second, they decrease the use of chemicals in the short-run, and thus extend their useful life. Third, they provide options *vis-à-vis* the adoption of new biotechnological packages. Fourth, because many insect problems are localized, large companies may be unwilling to do the needed research if markets are not large enough. Chemicals were crude weapons which worked against most pests; biological controls will be much more site-specific and demanding of local research capabilities.

This type of capability requires considerable development of human resources in insect biology, plant genetics, IPM techniques, and what has been termed "ecological engineering." These areas are not receiving enough attention, as resources are devoted to the techno-fix of super plants, although Brazil has listed biological controls as a priority (Pinheiro 1985). And Latin American agriculture, as with U.S. agriculture, continues to apply massive quantities of chemicals without sufficient attention to the inevitable consequences.

An interesting alternative to high-tech input packages which arose in our discussion is the possibility of carrying on an organic agriculture. This often leads to slightly lower yields, but purchased input costs are significantly lower. U.S. agriculture appears to be headed in both directions at the same time, with increasing research efforts devoted to each.

We can envision that in developed countries this type of organic agriculture may flourish, as it caters to an affluent consumer group who can afford essentially "handmade" or "craft" food. This would be in contrast to an increasingly high-tech, possibly synthetic, and genetically altered food production based on biotechnology for mass consumption, in which conventional agriculture plays a diminished or negligible role. In Latin America, will peasants be marginalized as craft food producers, or could this improve the terms of trade of their products?

We already see this type of division occuring in the United States as frozen prepared foods expand at the same time as consumption of organics and fresh fruits and vegetables also increases. In meat production, the new breeds and improved feeding technology in confined broiler raising have greatly lowered the price and led to increased mass consumption of chicken in such areas as fast foods. At the same time, it has created demand for an organic, range-fed poultry industry with much higher costs and prices. Perhaps this is just an extension of the substitution of chemical fibers for cotton and wool, or perhaps it is the advent of the final industrialization of agriculture.

Peasants

The foregoing discussion just reinforces the dilemma of the peasantry and biotechnology. If biological techniques are increasingly site specific, who will do the research for the peasants and how will it be paid for?

It would appear that there will be a significant role for the public sector in this area. For example, the savings in time and expense required to develop new crop varieties which come from biotechnological techniques such as tissue culture and recombinant DNA will permit greater attention to locally adapted varieties (Riggs 1985). Thus, highly localized and appropriate varieties could be offered to peasants. One can imagine a biotechnology that rediscovers the agroecology of the peasantry that combines improved resistant varieties with biological controls and low-cost organic methods (Viniegra 1985; Morales 1985).

However, biotechnology, insofar as it raises yields (cuts losses), will serve to remove the economic justification for aiding the peasantry, as peasants will become less important suppliers of urban wage foods. This would make peasant-oriented research a purely social issue. One cannot be overly sanguine about the prospects for such research given the poor record of the past.

Patents and Property Rights

A third dilemma biotechnology presents for Latin America is the increased privatization of property rights in agricultural techniques. Recent laws and court rulings in the United States imply that virtually every process or product arising from biotechnological research will be patented. As yet, there is no world agreement on patenting new life forms, but the imminence of products coming on the market, many of which will be of great benefit in Latin America, lends urgency to a resolution.

Much of the world's germplasm resources for basic crops is located in Latin America and other developing countries. The use of this diverse material has allowed plant breeding the success it has had and provides the basis for all future genetic engineering. The annual value of the export of this material from Latin America has been estimated to be from hundreds of millions of dollars to tens of billions of dollars (Kloppenburg and Otero 1985; Goldstein 1985).

The developing countries, irritated at giving away germplasm and then buying it back as seeds, have taken the position in the FAO debates that **all** plant genetic resources should be public property or else they will deny transfer of primitive cultivars out of their countries (Kloppenburg and Otero 1985). This is unrealistic both because it denies the commercial value of privately held germplasm and because it assumes the countries can control export. A more realistic approach is to find a way to make developed countries pay for the genetic material and allow patenting to proceed (Luiselli 1986; Kloppenberg and Otero 1985). Goldstein proposes such a solution, which requires both gathering and genetic work:

Germplasm and germplasm-derived dollars should be computed, perhaps, as part of the repayment of the Latin American debt. This, in turn, will be possible if and only if the region is capable of understanding the full meaning and extent of its resources, and can protect the valuable material. Protection, however, means patents, and patent claims will be granted only if Latin American countries can molecularly characterize their flora and fauna, add and subtract and transport useful genes... To stop the robbery of germ plasm, Latin America needs to transform its commodities by adding scientific value to them, or at least to tag them in such a manner that they become patentable in the central countries. If this is done, the region has a chance of becoming a partner of developed countries, not a mere backyard.

Latin America needs access to new biotechnologies. In many cases it is utterly dependent on the TNCs to transfer technology. Thus, it must come to terms with patenting or exclude itself. The rules of the game are already in place, and Latin America needs to play the game to win with those rules by turning patenting to its own advantage.

Patent Offices should be upgraded. "More often than not, the examiners of the Patent Offices are not trained in molecular biology. They do not understand the meaning and the technology involved and, therefore, cannot give a serious appraisal of patent claims. This means that patents will be approved that do not contain adequate descriptions and are, therefore, useless as instruments of know-how" (Goldstein 1985: 12-13).

Public sector work should be closely watched and improvements patented. The developed countries do this, and its neglect only acts to the detriment of the balance of payments. In addition, careful patenting, combined with improved basic science, might make Latin America a more attractive place for TNCs to do R&D beyond the merely adaptive work contemplated now (Goldstein 1985). The scarce resources available in Latin America for research suggest that using the TNCs to advantage is an important strategy.

Of course, the embrace of patents may make it necessary for the public sector to provide open pollinated varieties or subsidized hybrids for the peasantry. There is no doubt that the technological rents captured in patents present an obstacle to the wide diffusion of new biotechnologies in Latin America (Buttel, Kenney, and Kloppenburg, Jr. 1985). But this is not sufficient cause to forsake selling a resource now given away.

Conclusion

There is little question that biotechnology will transform agriculture in the next 30 years. An enormous research effort is being mounted at present, directed to a large extent by TNCs in cooperation with industrialized country governments and their universities. While progress has not been made in agriculture as rapidly as first predicted, new products are already being tested which will have profound consequences.

However, the efforts being made in this research, and hence its effects, are skewed toward products seen as immediately profitable. Thus, the effort and impact will vary by crop. Since different crops are often produced by different strata of producers in Latin America, this suggests that private sector biotechnology will affect agriculture unevenly. The input TNCs will produce biotechnology products for some crops and land types; producer groups will probably fund research for other crops, such as bananas and coffee; and agroindustrial TNCs will fund and/or transfer new technologies for many specialty exports and industrial crops. To the extent Latin American farm products compete in world markets, such transfers will be increasingly essential to maintain competitiveness.

But biotechnology will make land less important and inputs more so. This is often seen as the failure of Latin American land reforms: that they distributed only land at a time when access to credit and technology became essential (Arroyo 1981). Thus, if peasants are to be included, the public sector will have to undertake research directed toward specific crops and environmental conditions that may not be profitable for the private sector. Because biotechnology will speed up the technological treadmill, increase production, and put downward pressure on prices, peasants will become increasingly marginal producers without assistance.

Table 40 shows present biotechnology research in 82 Latin American institutions by crop. Some peasant crops (roots and tubers) and industrial crops head the list. This may be because these crops are most amenable to the techniques (tissue culture) being used in Latin America (Roca, Amezquita, and Villalobos 1986). However, governments and research directors should carefully consider how the limited resources available can best be utilized where the private sector will not be active. (Appendix 1 lists some research in the United States in plant biotechnology.)

To achieve the goals of being able to adapt new biotechnologies, to take up the slack where no research is being done, and to mount credible efforts in biological pest control, Latin America will have to have significantly increased human resources in plant and insect genetics and other basic sciences. Also, research efforts, whether national or cooperative, will have to be more carefully focused, and some division of labor should be found between national programs and the International Agricultural Research Centers. Biotechnology, as a techno-fix, will not solve the social problems of Latin American agriculture; in fact, unless considerable effort is given to mitigating its impact, it will clearly worsen inequality, flowing only to those who can afford to adopt it.

TABLE 40

Tecnologías Actuales: Organismos que se Estudian con Mayor Frecuencia en Proyectos de Biotecnología

Grupos y organismos bajo estudio	Instituciones que estudian cada grupo de organismos[a]		Proyectos que incluyen cada organismo[b]	
	número	por ciento	número	por ciento
Raíces y tubérculos	34	14.1		
Papa			62	7.8
Camote			33	4.1
Yuca			23	2.9
Industriales	25	10.4		
Café			19	2.4
Caña de azúcar			17	2.1
Palma aceitera			11	1.4
Cacao			10	1.3
Frutales tropicales	22	9.1		
Plátano/banano			28	3.5
Cítricos			11	1.4
Leguminosas de grano	21	8.7		
Frijol			35	4.4
Cereales	18	7.5		
Maíz			18	2.3
Trigo			16	2.0
Arroz			11	1.4
Bacterias	-- [c]	--		
Rhizobium			31	3.9
E. Coli			25	3.1
Hortalizas	13	5.4		
Tomate			14	1.8
Hongos	13	5.4		
Neurospora			10	1.6
Ornamentales	11	4.5		
Clavel			6	0.8
Virus	11	4.5		
Rotavirus			8	1.0
Forestales	10	4.1		
Eucalipto			10	1.3

a Grupos de organismos: citados 10 o más veces por las diferentes instituciones.

b Organismos individuales: citados 6 o más veces en los proyectos de investigación.

c No existe información.

Source: Roca, Amézquita, and Villalobos (1986).

7

IMPLICATIONS FOR AGRICULTURAL TECHNOLOGY IN LATIN AMERICA

The two discontinuities that Latin American agricultural technology needs to overcome - the discontinuity in prices and public budgets brought about by adjustments to the debt crisis and the discontinuity in scientific knowledge created by the biorevolution - pose major challenges for the design of a technological policy. While the crisis creates a new urgency for enhanced productivity growth in agriculture, this comes at a time when Latin America is least able to afford the necessary public sector investments. Even inaction will not preserve the status quo as the ongoing biorevolution in the MDCs will allow them further import substitution in raw materials of agricultural origin and will enhance the comparative advantages in agriculture. A major national and continental effort is needed to adjust Latin American agricultural technology to its new economic context and to make it a full beneficiary of the biorevolution.

Some key policy areas which we have identified for these purposes are:

• The need for a major redesign of the public sector research institutes in order to reduce internal inefficiencies; insure consistency of their priorities with a broader technological policy and with microeconomic policy; enchance their flexibility in resource use and their access to basic science in the national and foreign universities; create associations with input companies, agroindustry, and user groups to diversify and stabilize their sources of funding; and stress the social role of public research toward peasants and environmental concerns. These institutes which were organized to give them maximum autonomy in setting research priorities and in managing budgets must now seek flexible associations with other sources of technology and with the users of technology to both increase their resource pool and make their work more effective. From institutions with virtual technological monopoly, they must be transformed into partners of multiple and flexible technological ventures.

• Participation in the expected benefits of the biorevolution will require major institutional changes in the organization of Latin American research and development. The largely private nature of the source of biotechnical advances will require reforms in the laws governing patents and property rights; internationalization of research through contracts with TNCs, foreign venture capital firms, and foreign universities; a new role for the International Agricultural Research Centers (IARC) in helping link upward with basic science and in delivering downward technology for the social sectors and geographical areas neglected by private capital; and a great degree of flexibility in research contracts and of diversity in sources of funding.

Key to any successful program of technological change for Latin American agriculture is the quality of its human resources. The erosion of Latin American universities and the depletion of human capital are two of the most dramatic consequences of the economic crisis. International support to the institutions of higher learning and to training abroad is thus an urgently needed use that Latin America must make of foreign aid opportunities.

APPENDIX 1

A SAMPLE OF APPLIED PLANT BIOTECHNOLOGY RESEARCH RELATED TO AGRICULTURE

Disease and Herbicide Resistance in Plants

University

University of California, Davis, R. Michelmore. Disease resistance in lettuce.

University of California, Davis, L. Rappaport, Fungal resistance in celery.

University of California, Davis, J.N. Rutger. Herbicide resistance in rice.

University of California, Davis, M. Saltveit. Russet spot resistance in lettuce.

University of California, Riverside, N. Keen. Resistance in soybeans.

Cornell University, O.C Yoder. Fungi disease resistance.

Israel Weiz mann Institute, M. Edelman. Herbicide resistance.

University of Kentucky, J. Kuc. Plant inmunization.

Oklahoma State University, E.E. Sebesta. Disease resistance in wheat.

University of Oregon, D.I. Mills. Disease resistance in legumes.

University of Wisconsin, R.S. Hanson. Disease resistance.

Corporate

Allelix, Ontario, Canada. Resistance in potatoes (through cell fusion).

Agrigenetics Corp., Denver, CO and Madison, WI. Disease resistance in cereals and legumes.

Asgrow Seed Co., U.S. Disease resistance.

Calgene, Davis, CA. Herbicide resistance.

DeKalb-Pfizer Genetics, U.S. Herbicide resistance in corn.

DuPont Co. Experiment Stations, Wilmington, DE. Resistance to disease, herbicides, and insects.

International Plant Research Institute, San Carlos, CA. Disease resistance in wheat.

Koppers/DNA Plant Technology Corp., U.S. Diagnostic kits for plant diseases of citrus and turf grasses.

Nippon Shinayaju, Kyoto, Japan. Herbs with worm-repellent seeds.

Phytogen Inc., Pasadena, CA. Disease resistance.

Crop Improvement

University

University of California, Davis, A.B. Bennett. Tomato.

University of California, Davis, C. Meredith. Grape.

University of California, Davis, C.F. Quiros. Celery, cool season crops.

University of Guelph, Ontario Agricultural College, K.J. Kasha. Barley.

Iowa State University, P.A. Peterson, Maize.

Kansas State University, J. Shepard. Potatoes.

University of Minnesota, B.G. Gengnebach and J.L. Geadelmann. Maize.

Purdue University, B.A. Lankins. Cereals and legumes.

University of Wisconsin, O. Nelson. Maize.

Corporate

Advanced Genetic Sciences, Greenwich, CT. Potatoes, asparagus, strawberries.

Agricultural Genetics Co., Ltd, U.K. Plant breeding.

Asahi Chemical Industry, Ltd./ Hitachi Ltd., Japan. Rice, soybeans, other cereals.

Campbell Soup Company, U.S. Tomatoes.

Cetus, Madison, WI. Crop improvement.

DeKalb-Pfizer Genetics, DeKalb, IL. Corn, sorghum.

DNA Plant Technology Corp., Cinnamison, NJ. Tomatoes.

Frito-Lay Inc., Dallas, TX. Potatoes.

Kikkoman, Japan. Seed biotechnology.

Kirin Brewery, Japan. Seed biotechnology.

Life Sciences Inc., St. Petersburg, FL. Bulbs, seeds.

Mitsubishi, Japan. Seed biotechnology.

Mitsui Toatsu Chemicals Inc./ Kirin Brewery Ltd., Japan. Carrots and eggplant.

Mogen International, Leiden, Holland. Agronomic crops.

Molecular Genetics, Inc., Minnetonka, MN. Corn, cereals, sorghum.

Native Plants, Salt Lake City, UT. Agronomic crops and microorganisms.

Sungene Technologies Corp., San Francisco, CA. Crop varieties.

Twyford Labs, Glastonbury, U.K. Crop improvement.

Government

International Centre for Genetic Engineering and Biotechnology, U.N. Rice.

Consultative Group for International Agricultural Research. FAO, U.N. (13 nongrofit international research institutes). Rice, potatoes, maize, legumes, wheat.

Plant Growth Enhancement and Environmental Tolerance

University

University of Arizona, G. Tollin and R. Jensen. Photosynthesis.

University of California, Berkeley, W.C. Taylor. Photosynthesis.

University of California, Berkeley, S. Lindow. Frost prevention bacteria.

University of California, Davis, K.J. Bradford. Influences on plant growth hormones.

University of California, Davis, M. Matthews. Water stress in grape leaves.

University of California, Davis, C. Meredith. Genetic resistance to mineral stresses.

University of California, Davis, R. Valentine. Nitrogen fixation, osmotic stress tolerance.

University of California, Davis, J. Yoder. Genetic resistance to disease, salt, and cold in tomatos.

University of California, Riverside, I.P. Ting. Nitrogen fixation.

University of California, San Diego, S.H. Howell. Photosynthesis.

University of California, San Diego, D. Helinski. Nitrogen fixation.

University of Chicago, R. Haselborn. Nitrogen fixation.

Cornell University (Boyce Thompson Institute), A. Szalay. Nitrogen fixation.

Cornell University, M. Alexander, V. Gracen, and E. Earle. Nitrogen fixation.

Harvard University, L. Bogorad. Photosynthesis.

Harvard University, F.M. Ausubel. Nitrogen fixation.

University of Indiana, H. Gest. Nitrogen fixation.

Iowa State University, A.G. Atherly. Nitrogen fixation.

Kansas State University, L.C. Davis. Nitrogen fixation.

University of Maryland, S.O. King. Photosynthesis.

University of Michigan, R. Helling. Photosynthesis.

Michigan State University, C.P. Wolk and K. Schubert. Nitrogen fixation.

University of Missouri, J.D. Wall. Nitrogen fixation.

University of North Carolina, G.H. Elkan. Nitrogen fixation.

Temple University, R.E. Goldberg. Nitrogen fixation.

University of Utah, J.Y. Takemoto. Photosynthesis.

University of Wisconsin, W. Brill. Nitrogen fixation.

Corporate

Advanced Genetic Sciences, U.S. Frost protection bacteria.

Agricultural Genetics Co., Ltd., U.K. Microbial innoculants.

Calgene, Davis, CA. Genetic engineering for nutrient efficiency, stress-salt tolerance.

Cetus Corp., Berkeley, CA, Nitrogen fixation, inoculants.

Ciba-Geigy, Research Triangle Park, NC. Plant-bacterial interactions.

DuPont Co. Experiment Station, Wilmington, DE. Growth regulation.

International Plant Research Institute, San Carlos, CA. Stress resistance in wheat.

Native Plants Inc., Salt Lake City, UT. Stress tolerance.

New Plant Products, Cambridge, U.K. Rhizobium innoculants.

Ortho Research Center, Richmond, CA. Plant growth enhancers.

Phytogen Inc., Pasadena, CA. Photosynthesis.

R and A Plant/Soils Inc., Pasco, WA. Microbial soil inoculants.

Government

Indian Agricultural Research Institute, New Delhi, India. Blue-green algae biofertilizer for rice.

Crop Pest Control

University

University of California, Davis, P. Baumann. Biological control of pea aphid.

Cornell University, W. Roelofs. Insect control.

University of Idaho, L.A. Bulla. Microbial insecticides.

University of Idaho, L.K. Miller. Viral insecticides.

University of Massachusetts, C. Ying. Gypsy moth control.

North Carolina State University, R.L. Mott. Fusiform rust on pine and oak trees.

Texas A&M University. M. Summers. Viral insecticides.

Corporate

Agricultural Genetics Company, Ltd., U.K. Biological control products.

Bayer, U.S. Biotech insecticides, fungicides, and herbicides.

Biogen, U.K. Biodegradable herbicides.

Biotechnology General Corp., Tel-Aviv, Israel. Fungi to protect plants from microorganisms.

Ciba-Geigy, Research Triangle Park, NC. Crop protection chemicals.

DuPont Co. Experiment Station, Wilmington, DE. Crop protection chemicals.

Genentech, Inc., U.S. Agricultural pest control.

Ortho Research Center, Richmond, California. Agricultural pest control.

Zoecon Corp., Palo Alto, CA. Pest control.

Government

Hokkaido National Agricultural Experiment Station, Japan. Vaccine against cucumber mosaic virus for tomatoes, pimentos, and melons.

Microbial Resources Ltd. U.K. Bacterial, fungal, and viral pesticides.

Tree Improvement

University

University of California, Davis, A.M. Dandekar. Fruit and nut trees.

University of California, Davis. D.J. Durzan. Silviculture and pomology species.

Corporate

[6˜Calgene, Pacific, U.S. Tree improvement.

Genetics Lab, U.S. Fruit tree grafting.

Native Plants, Salt Lake City, UT. Tree improvement.

Oji Paper Co., Kameyama, Japan. Cell fusion for tree improvement.

Simpson Timber Co., Seattle, WA. Tissue culturing for controlled breeding of Coastal redwood.

Weyerhaeuser Co., Centralia, W.A. Tissue culturing for Douglas fir.

Government

United States Forest Service (with Calgene), U.S. Tree improvemment.

Miscellaneous Plant Biotechnology

Corporate

Agra-Cetus, U.S.

Allied Chemical Corp., U.S.
American Cyanamid Co., U.S.
ARCO Plant Cell Research Institute, U.S.
Biotechnia International, Inc., U.S.
Centaur Genetics Corp., U.S.
Crop Genetics International, U.S.
Dow Chemical Co., U.S.
Ecogen, U.S.
Eli Lily and Co., U.S.
Enzo Biochem, Inc., U.S.
General Foods Cor., U.S.
Genetics Institute, U.S.
Genetics International, Inc., U.S.
W.R. Grace and Co., U.S.
Ingene, U.S.
International Genetic Engineering, Inc., Santa Monica, CA.
International Genetic Sciences Partnership, U.S.
International Minerals and Chemical Corp., U.S.
Martin Marietta, U.S.
Miller Brewing Co., U.S.
Multivac, Inc., U.S.
Nabisco, Inc., U.S.
Neogen Corp., U.S.
Pfizer, Inc., U.S.
Phyto-Tech. Lab., U.S.
Pioneer Hybrid International Corp., U.S.
Plant Genetics, Inc., U.S.
Rohm and Haas, U.S.
Sandoz, Inc., U.S.
Sharing-Plough Corp., U.S.
A.E. Staley Manufacturing Co., U.S.
Standard Oil of Indiana, U.S.
Standard Oil of Ohio, U.S.
Stauffer Chemical Co., U.S.
Universal Foods Corp., U.S.
The Upjohn Co., U.S.
Worne Biotechnology, Inc., U.S.
Xenogen, Inc., U.S.

APPENDIX 2

COUNTRY DATA TABLES AND GRAPHS

Definitions and Sources

F-Elias, M-Elias: Fertilizer (in 1000 metric tons) and tractors; Elias - **Government Expenditures on Agriculture and Agricultural Growth in Latin America** International Food Policy Research Institute, Research Report 50, October 1985.

F-FAO: Consumption of Fertilizer (in 1000 metric tons), **FAO Fertilizer Yearbook.**

M-FAO: Number of Tractors, **FAO Production Yearbook.**

F*, M*: Series based on Elias until the year marked by a separation line in the tables and from the FAO data after:
F*(t)=F-FAO(t) * F-Elias(to) / F-FAO/to), and similarly for M*.

p, m, f: Index numbers of prices received by farmers and prices paid by farmers, **FAO Production Yearbook.**

w: For Latin American countries: monthly nominal wages in local currency unit, A. de Janvry, E. Sadoulet and L. Wilcox, **Rural Labour in Latin America.** Geneva: International Labour Office, Worl Employment Programme, Research Working Paper WEF 10-6/WP79, June 1986.

For Canada: Remuneration per day in Canadian $ and USA: Hourly wages for unskilled workers in the US$, International Labor Office, **Yearbook of Labor Statistics.**

GEA: Government Expenditures in Agriculture, Elias (1985).

R&E: Government Expenditures in Research and Extension, Elias (1985).

R&E stock: Accumulated R&E with 11% depreciation rate. Value in base year is 9.09 times R&E.

ResBud-ISNAR, ResBud/GRP: Public Resarch Budget and Public Research Budget per Agricultural Value-added (Gross Rural Product), ISNAR Data files.

ResBud-TP: Budget assigned to agricultural research; Trigo and Piñeiro - Funding Agricultural Research, in **Selected Issues in Agricultural Research in Latin America.** B. Nestel and E.J. Trigo (eds.), ISNAR, The Hague, 1984.

TABLE A2-1: Argentina

Years	F-Elias 1000 tons	H-Elias 1000 hp	F-FAO	M-FAO	F*/M*	p	m (index)	f	w (LCU)	GEA	R&E Elias	R&E stock	ResBud ISNAR	ResBud TP	ResBud/GR ISNAR (percent)
										(millions 1960 LCU)			(mill. 1975 LCU)		
1950		735								40.1	4	363.6			
1951		902								56.7	4.2	365.6			
1952		1 093								53.7	4.2	367.4			
1953		1 397								66.8	4.2	369.0			
1954		1 503								50.5	4.3	371.4			
1955		1 879								48.9	4.3	373.5			
1956	19.2	2 829			67.87					58.2	4.3	375.4			
1957	12.5	3 542			35.29					33.5	4.3	377.1			
1958	18.6	4 323			43.03					39	5.8	393.7			
1959	12.5	4 909			25.46					33.4	7.4	424.4			
1960	16	5 529		111	28.94					45.8	8.1	458.7		1 100	
1961	20.1	6 329		127	31.76					52.1	8.9	497.2			
1962	13.4	6 802		137	19.70					46.3	7.1	513.5	873.5		0.493
1963	33.9	7 318		147	46.32					44.1	7.1	528.0			
1964	46	7 994		150	57.54					53.6	9.6	566.0			
1965	46.6	8 579		152	54.32				88	53.5	8	583.7		1 067	
1966	50.1	8 909	50	155	56.24				117	62.1	9	609.5			
1967	51.8	9 248	65	160	56.01				153	74.6	14.6	688.4	852.2		0.665
1968	59	9 565	68	172	61.68				163	84.3	13.5	747.7			
1969	68.3	9 711	80	178	70.33				182	86.6	15.2	817.5			
1970	74.5	9 825	87	178	75.83				228	90.7	15.5	882.5		1 113	
1971	76.1	10 072	77	171	75.56				350	74.5	12.9	914.5		936	
1972	103.1	10 285	86	175	100.24				500	70.3	14.1	954.9	1 304.0	1 028	0.668
1973	81.4	10 779	83	180	75.52				898	66.5	18.4	1 033.8		1 283	
1974	72.5	11 273	75	184	64.31				1 282	71.2	11.9	1 039.1		1 534	
1975	40.5	11 471	60	188	35.31				3 366	68.3	17.6	1 100.8		1 222	
1976	80	11 945	78	190	66.97	100	100	100	10 058	78.1	14.9	1 128.7		1 145	
1977	72.2	12 445	74	195	58.02	244	247	150	25 517	92.4	13.1	1 135.6	1 324.6	1 165	0.826
1978	82.7	12 138	107	173	68.13	634	646	338	61 857	81.2	18.5	1 195.7		1 218	
1979	137.5	11 887	130	171	115.67	1 303	1 589	639		95.2	20.8	1 272.1		1 209	
1980	124.1	11 466	116	167	108.23	2 283	2 680	1 334		106.7	25	1 382.2		1 301	
1981	85.4	10 968	96	159	77.86	4 814	5 025	2 859							
1982			113	204	71.43	16 947	20 001	12 680					1 075.0		0.614
1983			131	202	83.63	85 387	92 933	48 370							
1984			156	204	98.62		263 532	160 168							

Figure A2-1

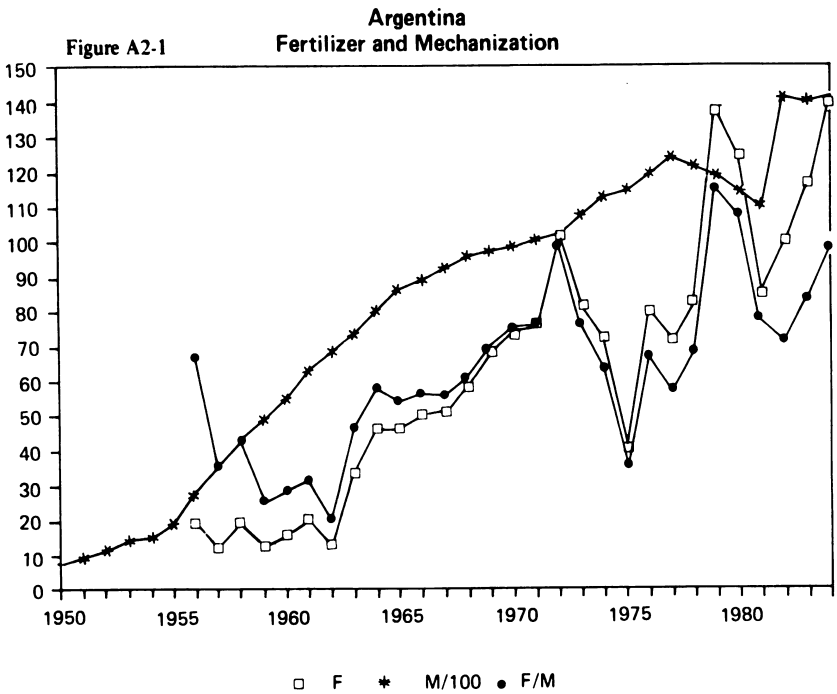


Figure A2-2

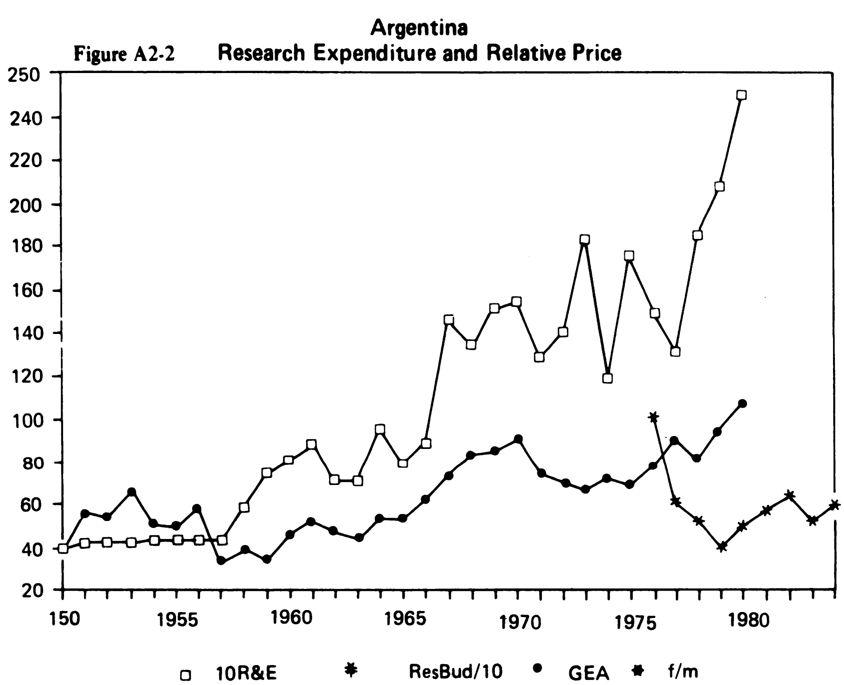


TABLE A2-2: Bolivia

Years	F-FAO 1000 tons	M-FAO units	F*/M* (0.001)	p	m (index)	f	GEA Elias (millions 1960 LCU)	ResBud TP (millions 1975 LCU)
1968	2						188.7	
1969	3						171.2	
1970	2						197.5	30.98
1971	4	386	10.4				175.4	31.36
1972	5	398	12.6				206.8	25.08
1973	5	689	7.3				269.7	25.62
1974	6	720	8.3	106		108	220.4	26.14
1975	3	759	4.0	100		100	251.1	24.82
1976	3	676	4.4	100		100	336.6	23.52
1977	4	665	6.0	133		74	374.9	41.24
1978	5	726	6.9	148	100	76	519.2	46.02
1979	3	750	4.0	154	112	103		42.08
1980	3	750	4.0	250	135	236		36.68
1981	7	740	9.5	284	153	264		
1982	3	750	4.0	345				
1983	8	760	10.5					
1984	5	770	6.5					

Figure A2-3 Bolivia Fertilizer and Mechanization

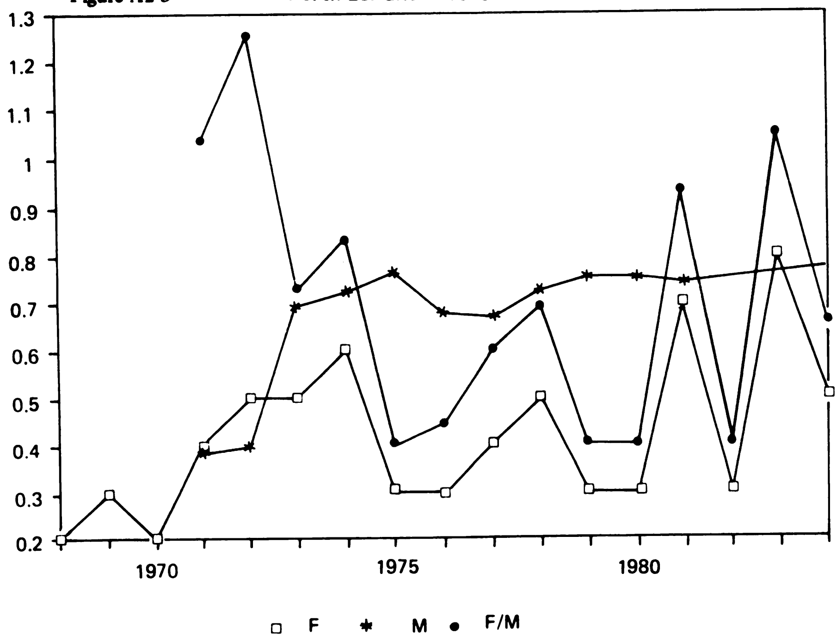


Figure A2-4 Bolivia Research Expenditure and Relative Price

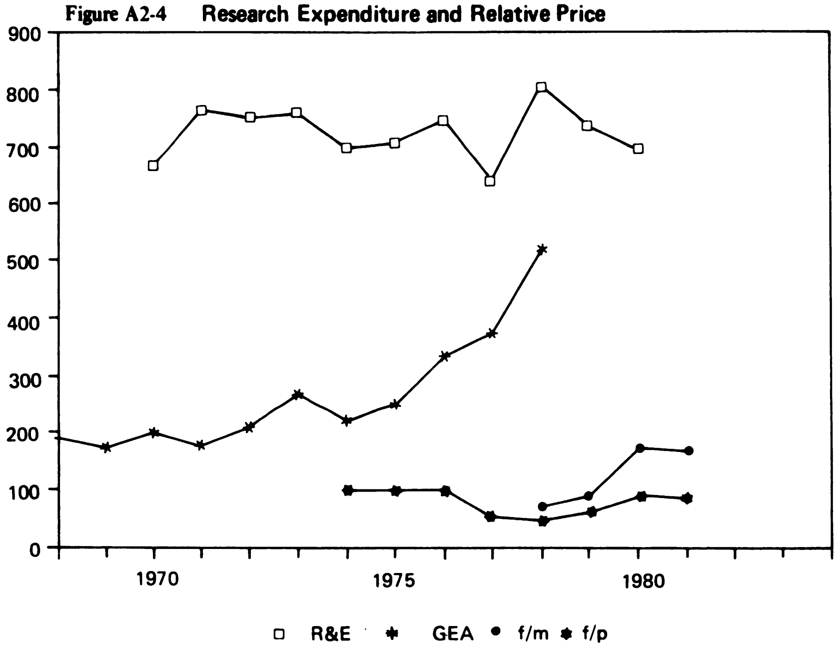


TABLE A2-3: Brazil

Years	F-Elias 1000 tons	M-Elias 1000 un.	F-FAO 1000 tons	M-FAO 1000 units	F*/M*	p 1966=100	m (index)	f	w (LCU)	GEA (millions 1960 LCU)	R&E Elias (millions 1960 LCU)	R&E stock (millions 1960 LCU)	ResBud ISNAR (mill. 1975 LCU)	ResBud TP (mill. 1975 LCU)	ResBud/GR ISNAR (percent)
1950	89	8.4			10.60						0.2	1.82			
1951	121	18.5			6.54						0.3	1.92			
1952	73	25.6			2.85					9.8	0.4	2.11			
1953	117	28			4.18					12.9	0.4	2.28			
1954	124	42.9			2.89					12.9	0.4	2.42			
1955	161	46.3			3.48					14.5	0.4	2.56			
1956	165	49.4			3.34					15.3	0.3	2.58			
1957	207	56.5			3.66					21.4	0.5	2.79			
1958	250	55.9			4.47					18.5	0.6	3.09			
1959	221	56.3			3.93					16.7	0.6	3.35			
1960	299	61.3			4.88					18.7	0.5	3.48		67.32	
1961	247	65.8			3.75					20.1	0.5	3.60			
1962	237	65.3			3.63					20.6	0.6	3.80	165.52		0.26
1963	314	70.4			4.46					19.3	0.6	3.98			
1964	255	76			3.36					24	0.5	4.04			
1965	290	74.5			3.89					25	0.9	4.50			
1966	281	79.9	256	82	3.52				49	23.5	1	5.00			
1967	449	91.2	409	83	4.93				64	27.8	0.9	5.35			
1968	602	103.4	543	88	6.17				75	27.7	1	5.77			
1969	630		630	92	6.85				88	28.1	1.5	6.63			
1970		165.9	1 002	99	10.12				107	31.1	1.2	7.10			
1971			1 123	166	6.77				136	30.2	1.4	7.72			
1972	1 624	201	1 624	175	9.28				164	34.5	1.5	8.37	635.53	196.57	0.63
1973	1 673	218.5	1 673	185	9.04				223	33.3	1.5	8.95		237.61	
1974	1 825	236	1 825	236	7.73				324	40.4	1.7	9.67			
1975	1 978	254	1 978	254	7.79	1 003			435	42.2	10.8	19.40			
1976	2 528	270	2 528	270	9.36	1 862			601	80	13.9	31.17		700.31	
1977	3 209	280	3 209	280	11.46	3 394			893	88.2	16.1	43.84	1 262.18	713.41	0.95
1978	3 222	300	3 222	300	10.74	3 726			1 286	125.3				758.03	
1979	3 437	320	3 567	320	11.15	5 224	100	100						945.24	
1980	4 006		4 201	330	12.73	10 187	178	217	4 293					949.56	
1981			2 753	340	8.10	17 500	442	469	9 058						
1982			2 729	655	4.17	29 463	946	908	18 145						
1983			2 272	710	3.20	30 665	2 035	2 674	40 594						
1984			3 428	765	4.48	99 204	7 151	8 469	122 079						

Figure A2-5

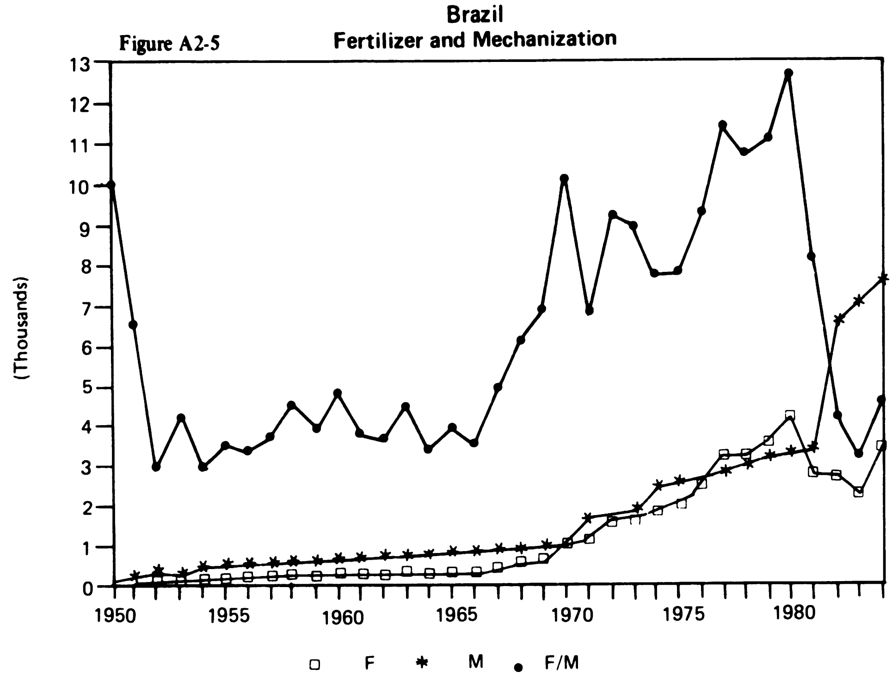


Figure A2-6

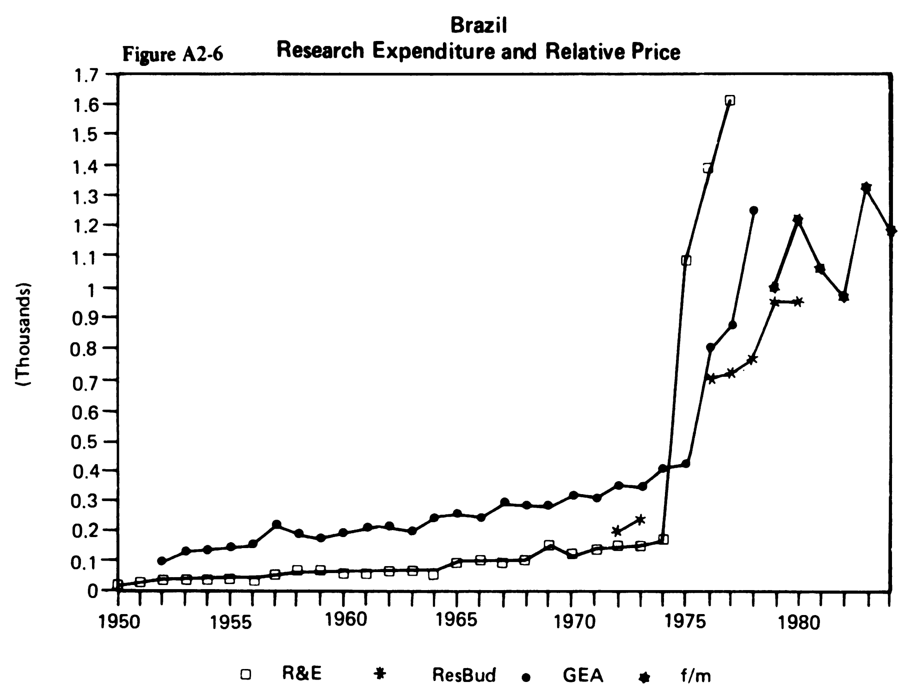


TABLE A2-5: Canada

Years	F-FAO 1000 tons	M-FAO 1000 un.	F*/M*	p	m (index)	f	w per day ILO (LCU)	ResBud ISNAR (millions 1975 LCU)	ResBud/GR ISNAR (percent)
1968	722			92.7	105		11		
1969	728			95.6	99	99.3	12		
1970	802			97.8	96	96.8	12.5		
1971	880	596	1.48	100	100	100	13.1		
1972	1 016	605	1.68	114	103	104	14	212.57	4.1
1973	1 209	616	1.96	203	107	117	16		
1974	1 240	617	2.01	274	121	166	18.6		
1975	1 308	626	2.09	246	140	205	22.4		
1976	1 336	634	2.11	226	149	200	25.6		
1977	1 625	646	2.52	214	159	200	28.4	185.41	2.571
1978	1 795	657	2.73	225	175	213	30.1		
1979	1 808	657	2.75	265	199	253	32.2		
1980	1 939	657	2.95	312	226	305	34.3		
1981	1 946	658	2.96	338	252	339	36.8		
1982	1 996	658	3.03	310	267	325	38.7	184.38	2.433
1983	2 241	658	3.41	312	277	305	40.8		
1984	2 379	658	3.62	326	285	319	42.6		
1985				291	280	322			

Figure A2-7

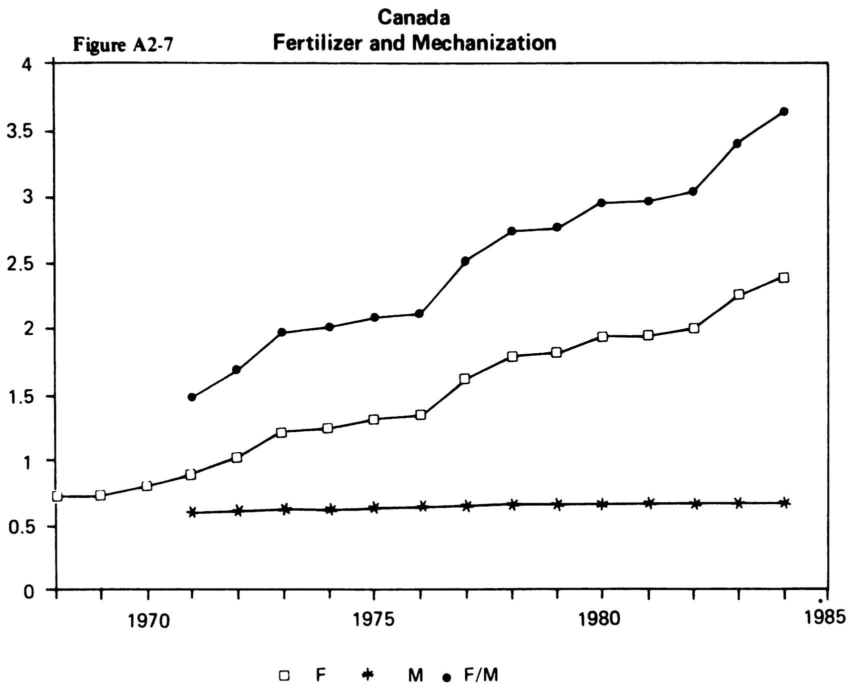


Figure A2-8

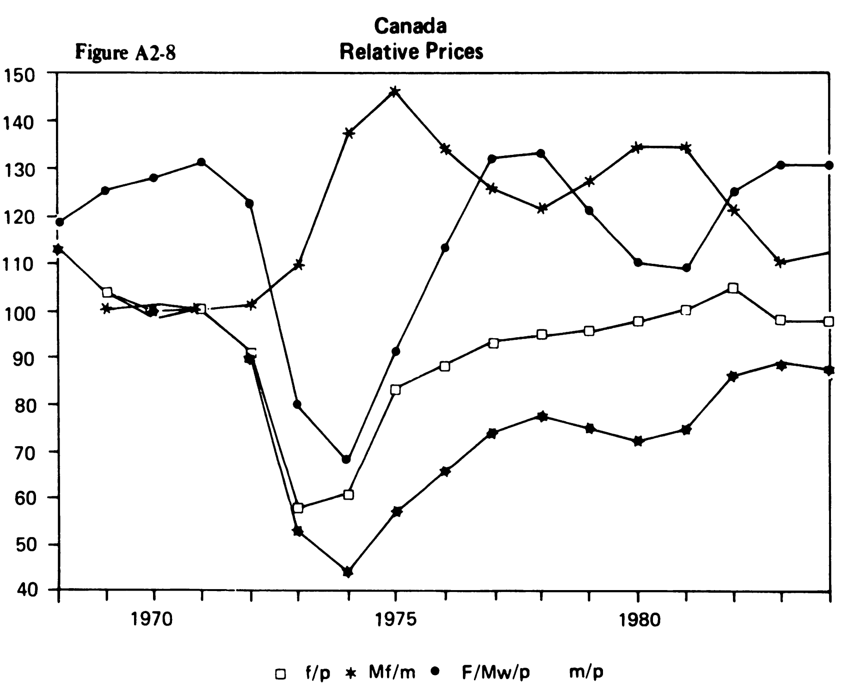


TABLE A2-4: Chile

Years	F Elias 1000 tons	M Elias 1000 un.	F*/M*	p	m	f	w minimum (LCU)	GEA	R&E Elias (millions 1960 LCU)	R&E stock	ResBud ISNAR (mill. 1975 LCU)	ResBud TP	RB/GRP ISNAR (percent)
1960								36.4	0.68	6.18		13.701	
1961								54.5	0.74	6.24			
1962								56.6	0.75	6.30	10.53		0.337
1963								61.1	0.79	6.40			
1964	122.9	22.5	5.46					46.4	0.72	6.42			
1965	122	22.9	5.33				68	56.4	1.13	6.84		13.554	
1966	142.9	23.8	6.00				117	68.6	1.32	7.41			
1967	125.7	25.3	4.97				153	77.8	1.75	8.34	15.04		0.636
1968	140.6	25.3	5.56				163	100.7	2.31	9.74			
1969	157.5	25.9	6.09				182	99.3	2.23	10.89			
1970	158	26.7	5.92				228	93.3	1.98	11.68		41.174	
1971	170	27.2	6.25				350	162.7	3.09	13.48		45.712	
1972	158.2	30.5	5.19				500	155.5	3.15	15.15	23.6	46.787	0.757
1973	197.4	31.9	6.19				898	109.2	2.75	16.23		26.745	
1974	169.8	31.6	5.37				1.282	85.1	3.21	17.66		28.69	
1975	102.8						3 366	123.5	3.15	18.86		26.151	
1976	119.7						10 058	61.4	3.48	20.27		33.252	
1977	105						25 517	72.4	4.36	22.40	27.12	32.958	0.765
1978	127.2						61 857	75.2				31.253	
1979	143.4						(index)					32.373	
1980							100*					33.208	
1981							120						
1982							121.5				22.92		0.653
1983							97.9						

Figure A2-9

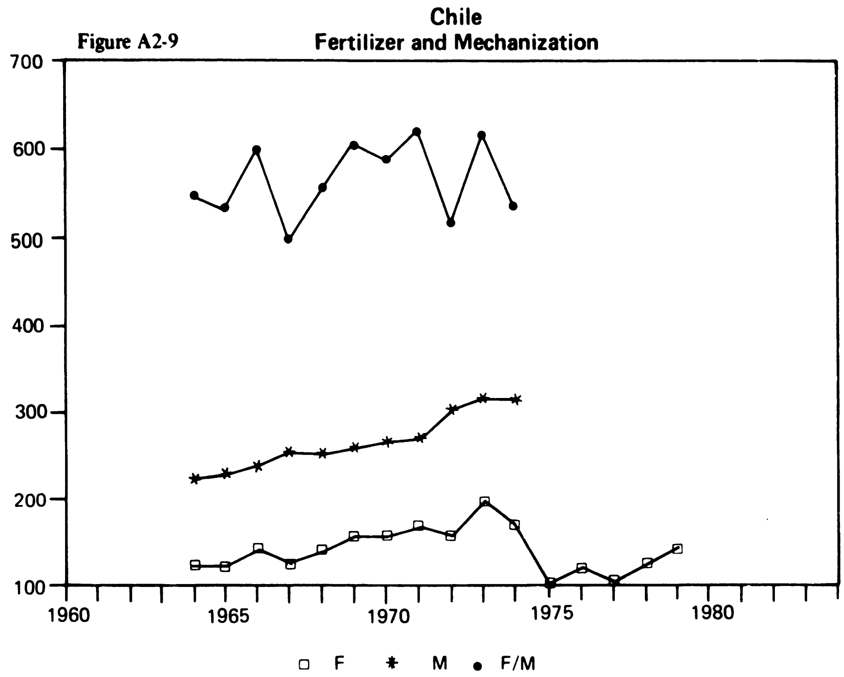


Figure A2-10

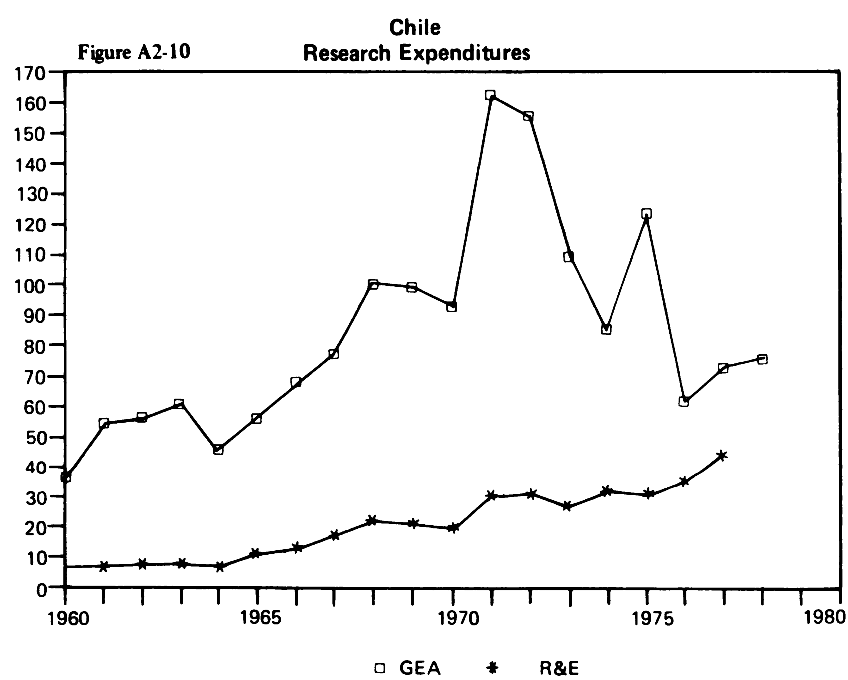


TABLE A2-6: Colombia

Years	F-Elias Index 1960=100	M-Elias millions units	F-FAO 1000 tons	M-FAO millions units	F*/M*	p	m (index)	f	w average (LCU)	w minimum (LCU)	GEA Elias (millions 1960 LCU)	R&E Elias (millions 1960 LCU)	R&E stock (millions 1960 LCU)	ResBud ISNAR (millions 1975 LCU)	ResBud TP (millions 1975 LCU)	ResBud/GR ISNAR (percent)
1950	26.8	6.5			4.12							16.9	153.6			
1951	34.2	7.9			4.33							19.4	156.1			
1952	31.1	8.8			3.53							26.1	165.0			
1953	34.1	10.1			3.38							22.8	169.7			
1954	64.1	12.2			5.25							27.5	178.5			
1955	60	13.9			4.32							29.7	188.6			
1956	76.2	15.4			4.95							29.6	197.4			
1957	91.9	15.3			6.01							22.3	198.0			
1958	100	16.3			6.13							25.9	202.1			
1959	135.3	17.3			7.82							25.8	205.7			
1960	123.7	18.4			6.72							26.1	209.2		213.8	
1961	148.8	19.2			7.75						92.87	35.9	222.1			
1962	175	20.1			8.71						111.49	32.2	229.8	324.9		0.409
1963	159	20.6			7.72						91.92	18.3	222.9			
1964	190.4	20.9			9.11						81.02	19.2	217.5			
1965	187	20.8			8.99				311	234	111.39	28.1	221.7		234.3	
1966	244.7	21.3	131		11.49				371	234	98.64	24.1	221.4			
1967	284.1	23.1	142		12.30				384	234	111.47	33.8	230.9	250.4		0.388
1968	305.9	25.1	148		12.19				405	234	159.31	47	252.5			
1969	270.6	25.8	141		10.49				494	236	205.27	52.8	277.5			
1970	267	26.5	144	27.9	10.08	100		100	502	260	249.42	57.2	304.2		667.9	
1971	288.2	27.4	184	28.7	10.52					260	298.7	60.7	331.4		764.8	
1972	299.7	28	206	29.8	10.70					267	253.72	100.8	395.8	286.8	750.6	0.342
1973	314.7	27.7	256	30.2	11.36	201		161		338	238.16	72.2	424.4		760.8	
1974	327.3	23.8	250	23.8	13.75	256		241		622	203.51	55.6	433.3		702	
1975	345.1	24.2	215	24.2	14.26	270		485		885	270.56	54.3	440.0		711.5	
1976	399.1	24.6	246	24.6	16.22	353		581	1 710	906	180.99	50.1	441.7		747.2	
1977	371.4	25.6	292	25	14.51	490		578	2 581	1 363	195.23	32.3	425.4	227.8	641.7	0.216
1978	340.7	26.7	291	26.5	13.64	499	456	585	3 244	1 756	239.28	47	425.6		807.5	
1979	341.3	27.7	312	27.5	14.09	635	529	619	3 926	1 979	230.49	52.4	431.2		739.9	
1980	368.5	28.8	312	28.4	13.65	782	610	868	5 070	3 640	246.51	37.1	420.9		697.1	
1981			280	29	11.99	963	769	1 309	6 266	4 602						
1982			325	28.6	14.11	1 300	936	1 512	7 384	6 084				204		0.249
1983			318	28.7	13.76	1 622	1 070	1 536	8 996	7 592						
1984			363	28.8	15.66	1 853	1 367	1 914	10 426	9 646						

Figure A2-11

Colombia
Fertilizer and Mechanization

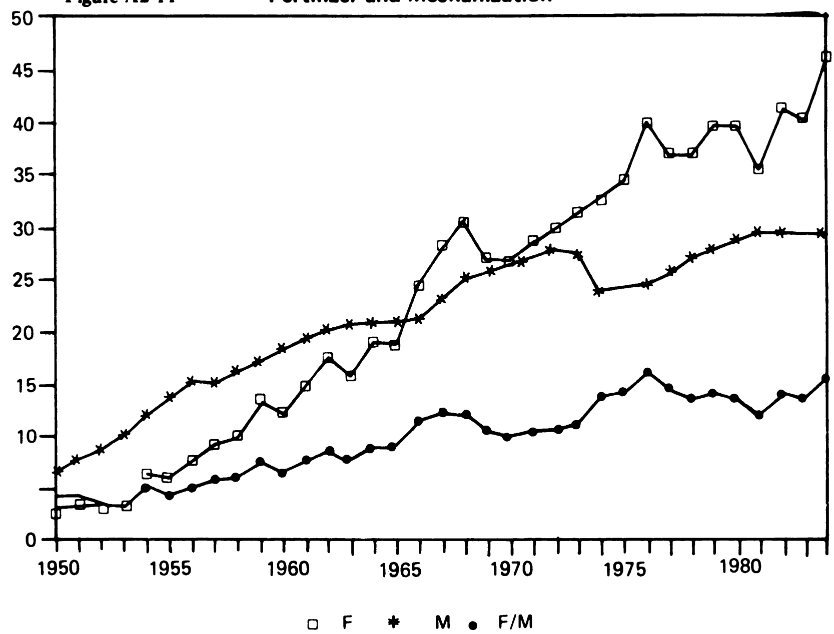


Figure A2-12

Colombia
Relative Prices

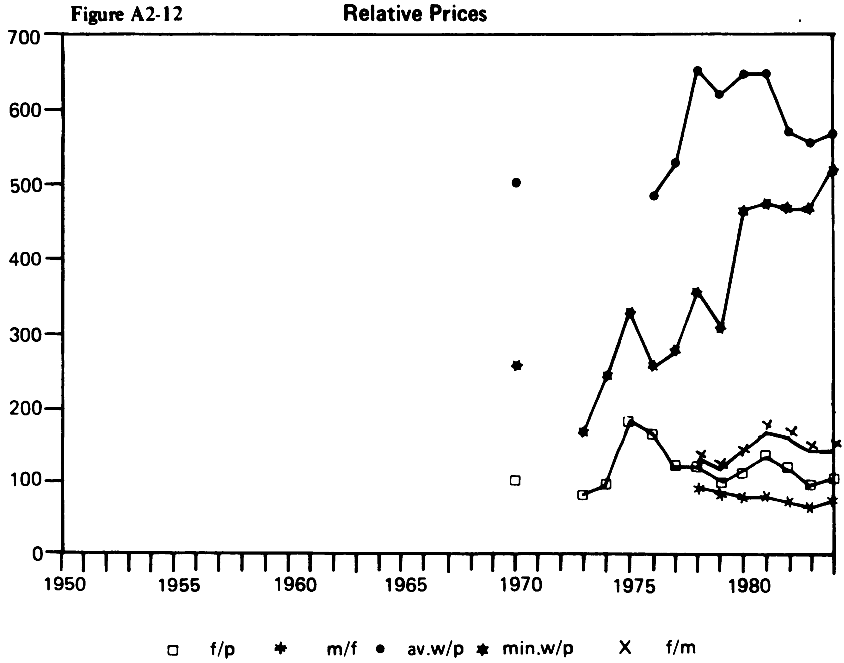


TABLE A2-7: El Salvador

Years	F-FAO 1000 tons	M-FAO units	F*/M*	p	m (index)	f	w minimum (LCU)	ResBud ISNAR (millions 1975 LCU)	ResBud TP (millions 1975 LCU)	ResBud/GR ISNAR (percent)
1968	58						68			
1969	54						68			
1970	65						68		1.28	
1971	81	2 100	0.039				68		1.55	
1972	95	2 150	0.044				68	1.53	1.81	0.152
1973	110	2 200	0.050				74		2.3	
1974	99	2 850	0.035				86		2.57	
1975	94	2 900	0.032	100	100	100	93		2.5	
1976	102	3 000	0.034	102	175	73	108		4.53	
1977	106	3 050	0.035	102	178	68	113	3.44	4.1	0.252
1978	112	3 150	0.036	110	179	70	128		5.08	
1979	75	3 250	0.023	112	180	79	156		4.41	
1980	60	3 300	0.018	139	193	101	156		3.91	
1981	88	3 320	0.027	174	210	124	156			
1982	60	3 340	0.018				156	3.17		0.211
1983	82	3 360	0.024				156			
1984	55	3 380	0.016				156			

Figure A2-13

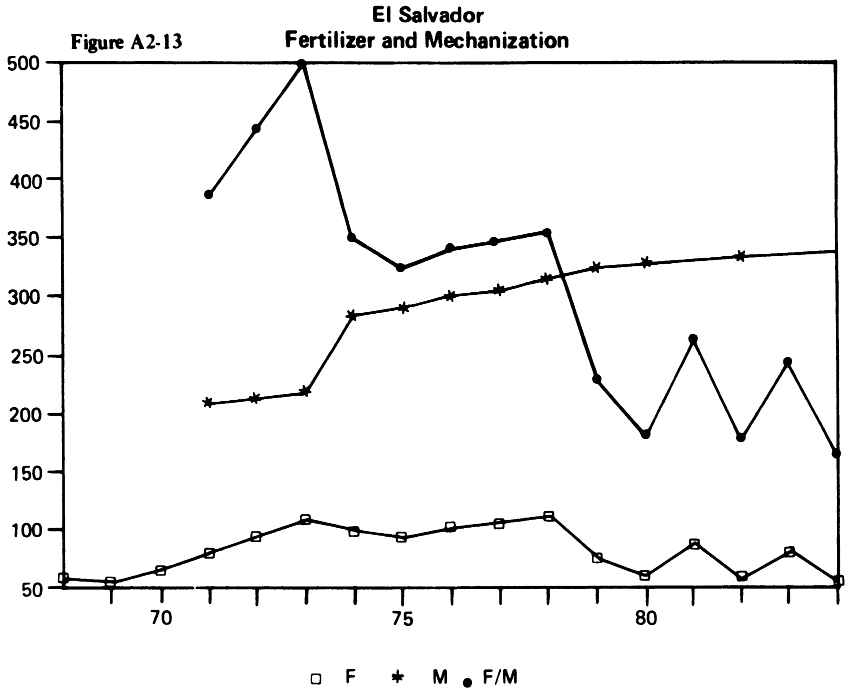


Figure A2-14

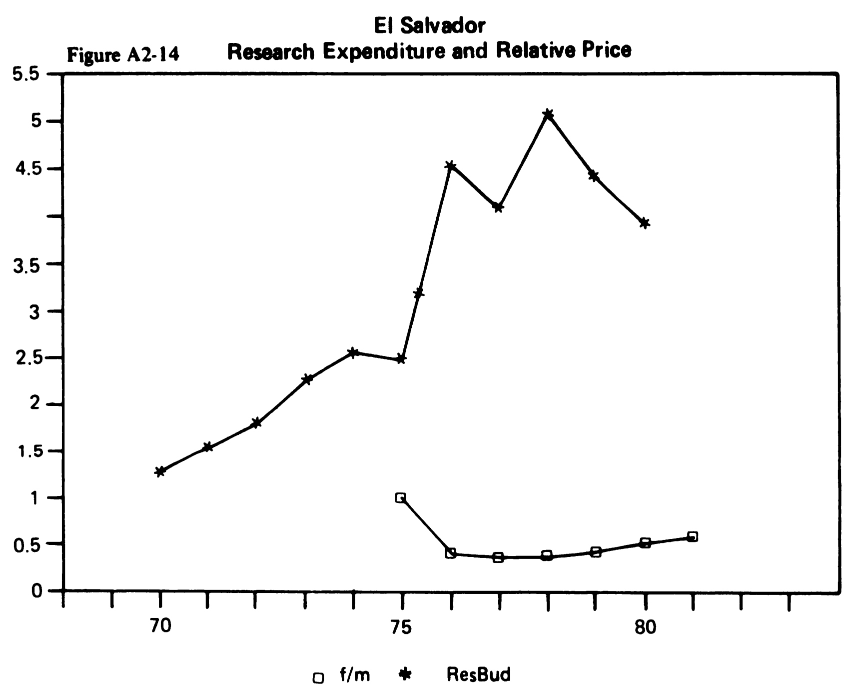


TABLE A2-8: Honduras

Years	F-FAO 1000 tons	M-FAO units	F*/M*	p (index)	m	f	w (LCU)	ResBud ISNAR (1000 1975 LCU)	ResBud ISNAR (percent)
1968	18								
1969	23								
1970	24								
1971	28	700	40						
1972	24	800	30	100					
1973	24	900	27						
1974	19	950	20	112			52		
1975	20	1 000	20	110			61		
1976	25	1 050	24	124			65		
1977	28	1 100	25	146			65	1.01	0.53
1978	23	3 060	7	151			66		
1979	20	3 160	6	150			78		
1980	29	3 290	9				95		
1981	28	3 280	9				121		
1982	24	3 300	7				130	1.23	0.69
1983	28	3 310	8				136		
1984	35	3 330	11				136		

Figure A2-15

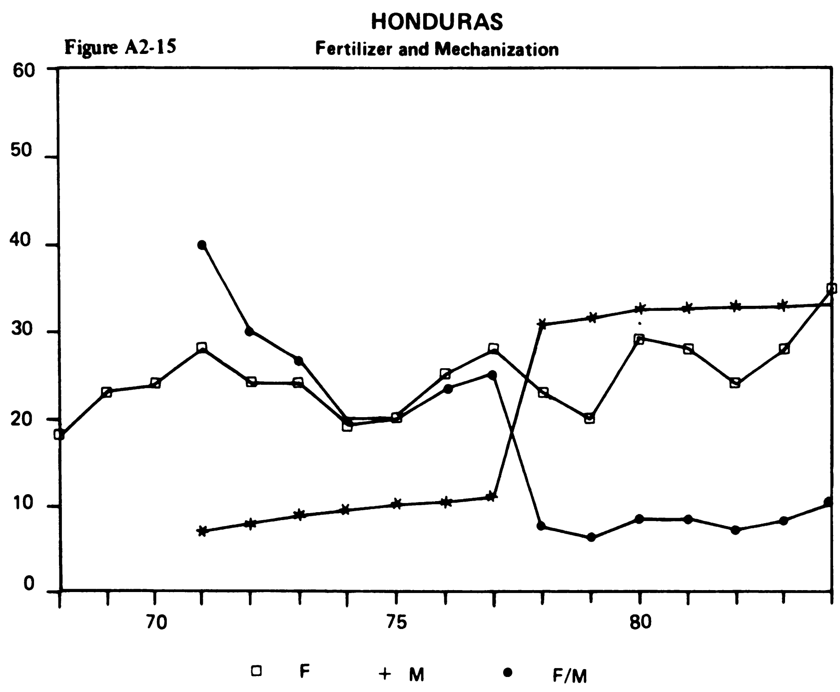

HONDURAS
Fertilizer and Mechanization
60
50
40
30
20
10
0
70
75
80
F
+ M
F/M

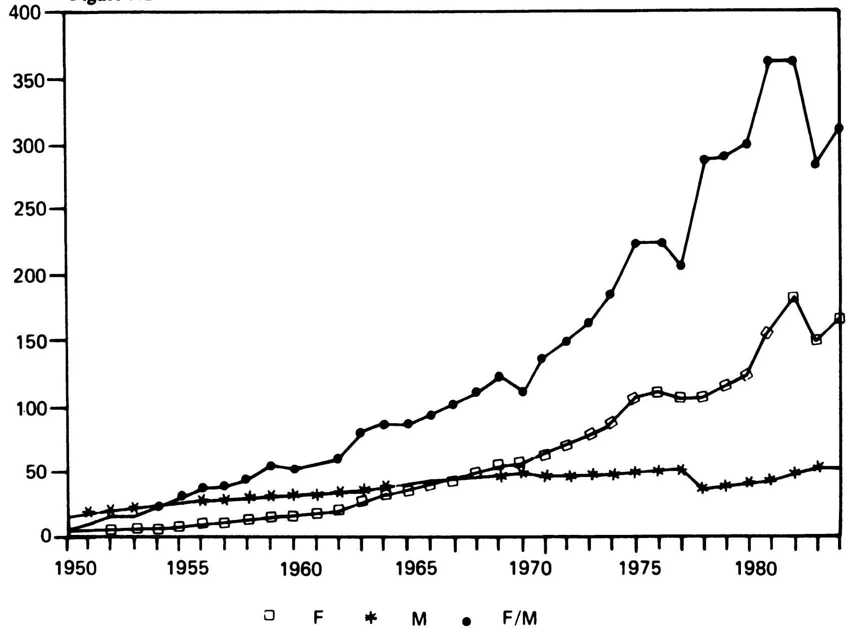
TABLE A2-9: Mexico

Years	F-Elias 1000 tons	M-Elias 1000 units	F-FAO 1000 tons	M-FAO 1000 units	F*/M*	p	m (index)	f	w minimum (LCU)	GEA Elias (millions 1960 LCU)	R&E Elias (millions 1960 LCU)	R&E stock (millions 1960 LCU)	ResBud ISNAR (millions 1975 LCU)	ResBud TP (millions 1975 LCU)	ResBud/GR ISNAR (percent)
1950	11.7	15.1			0.77					1 114	7.8	70.90			
1951	19.8	18.6			1.06					1 127	8.6	71.70			
1952	32.2	19.8			1.63					1 055	9.6	73.42			
1953	37.3	21			1.78					1 063	9.7	75.04			
1954	51.7	22.7			2.28					1 089	17.2	83.99			
1955	76.8	25.2			3.05					995	20.7	95.45			
1956	100.4	26.8			3.75					1 067	19.4	104.35			
1957	109.1	28			3.90					1 018	27	119.87			
1958	129.9	29.3			4.43					1 018	32.6	139.28			
1959	164.6	30.7			5.36					1 120	33.4	157.36			
1960	168.8	32.2			5.24					897	36	176.05		58.3	
1961	160.5	32.9			5.49					1 228	41.6	198.29			
1962	204.1	33.6			6.07					1 092	39.4	215.88	57.19		0.083
1963	280.7	34.6			8.11					1 634	36.4	228.53			
1964	321.4	37.1			8.66					2 236	38.8	242.19			
1965	343.3	39.3			8.74				364	1 328	38.8	254.35		67.2	
1966	390	41.6	397		9.38				454	1 414	75.4	301.77			
1967	430.6	42.2	436		10.20				453	2 245	100	368.58	49.6		0.063
1968	498.7	44.9	519	84	11.11	100	100	100	523	2 085	87.7	415.73			
1969	560.8	45.8	561	87	12.24	103	100	101	523	2 437	108.8	478.80			
1970	537.7	48.5	538	92	11.09	106	101	102	610	3 115	75.1	501.23		30.9	
1971	614.7	44.8	615	120	13.72	111	101	104	610	2 517	83.1	529.20		41.9	
1972	679.2	45.3	679	125	14.99	116	103	105	721	3 831	131.8	602.79	143.59	65.8	0.132
1973	780.1	47.6	780	130	16.39	152	109	107	764	4 882	123.5	659.98		109.3	
1974	864.5	46.5	864	135	18.59	187	138	133	1 037	6 101	38.3	625.68		116.8	
1975	1 073.5	48.2	1 073	140	22.27	220	154	133	1 198	8 358	190.6	747.46		173.4	
1976	1 135.7	51.3	1 120	145	22.44	219	239	140	1 556	5 632	171.2	836.44		199.9	
1977	1 035.5	50	1 068	150	20.68	295	249	209	1 986	10 300			346.56	166.6	0.275
1978		54.4	1 067	108	28.70	324	285	237	2 327	10 098				450.6	
1979		55.4	1 134	114	28.89	393	346	246	2 837	15 847				510.6	
1980			1 238	120	29.97	560	386	268	3 572	22 110				579.5	
1981			1 561	125	36.27	627	525	309	4 762						
1982			1 825	146	36.31	1 010	610	395	7 336				642.09		0.505
1983			1 486	152	28.40	2 031	1 427	603	11 126						
1984			1 661	155	31.13	3 432	2 587	1 365	17 535						

MEXICO

Figure A2-16

Fertilizer and Mechanization



MEXICO

Figure A2-17

Research Expenditure and Relative Price

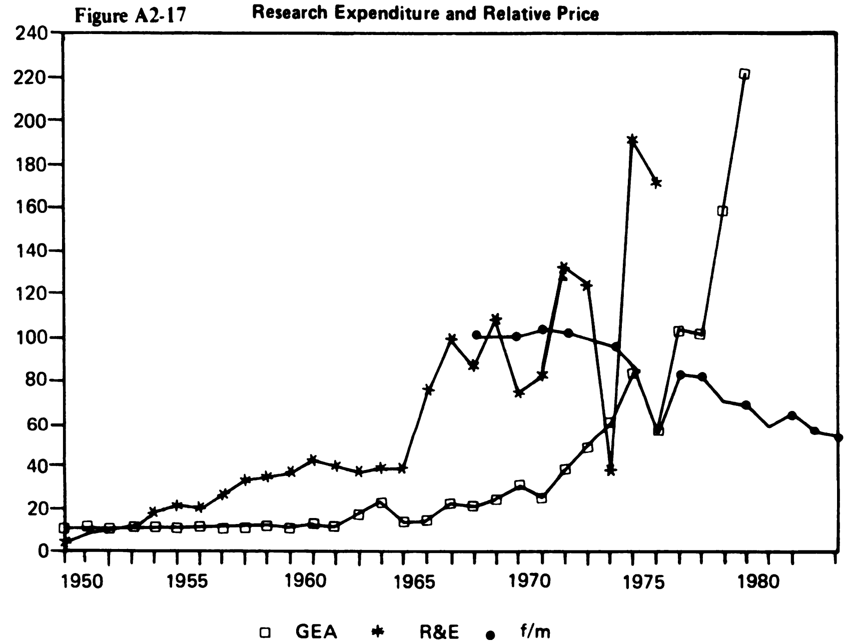


TABLE A2-10: Peru

Years	F-Elias 1000 tons	M-Elias 1000 un.	F-FAO 1000 tons	M-FAO 1000 units	F*/M*	p	m (index)	f	w minimum (LCU)	GEA Elias (millions 1960 LCU)	R&E Elias (millions 1960 LCU)	R&E stock (millions 1960 LCU)	ResBud ISNAR (mill. 1975 LCU)	ResBud TP (mill. 1975 LCU)	ResBud/GRP ISNAR (percent)
1960														76.9	
1961															
1962													101.7		0.173
1963															
1964															
1965									730					114.9	
1966			64						730						
1967			78						751				127.8		0.208
1968			68	11	6.18	100	100	100	864	970	87	791			
1969			82	11.5	7.13				982	933	49.9	754			
1970	81.5	10.9	84	12.3	6.83				1 055	1 279	83.3	754		351.8	
1971			82	11.5	7.13				1 253	1 068	109.2	780		271.3	
1972		11.5	122	12	10.17				1 318	1 255	111.8	806	305.9	289.4	0.387
1973	121.8	11.8	98	12.5	7.84				1 483	1 740	98.3	816		308.9	
1974	97.5	12	142	12	11.83				1 576	2 122	97.7	824		298	
1975	142	12.5	104	12.5	8.32	226	288	277	2 017	2 628	156.4	890		415.7	
1976	94	12.7	129	12.7	10.16	284	363	243	2 593	2 453	170.4	962		376.9	
1977	119.8	13	139	13	10.69	488	603	337	3 121	2 288	122.6	979	315.5	211	0.406
1978	133.4	13.3	137	13.3	10.30	886	1 052	599	3 884	1 960	88.9	960		189	
1979	128.2		117	13.6	8.60	1 421	1 200	1 308	8 607					174.6	
1980			118	13.9	8.49	2 286	3 461	1 874	13 771					161.2	
1981			132	14.3	9.23										
1982			93	16.5	5.64								317.4		0.544
1983			79	17.3	4.57										
1984			78	17.8	4.38										

Figure A2-18

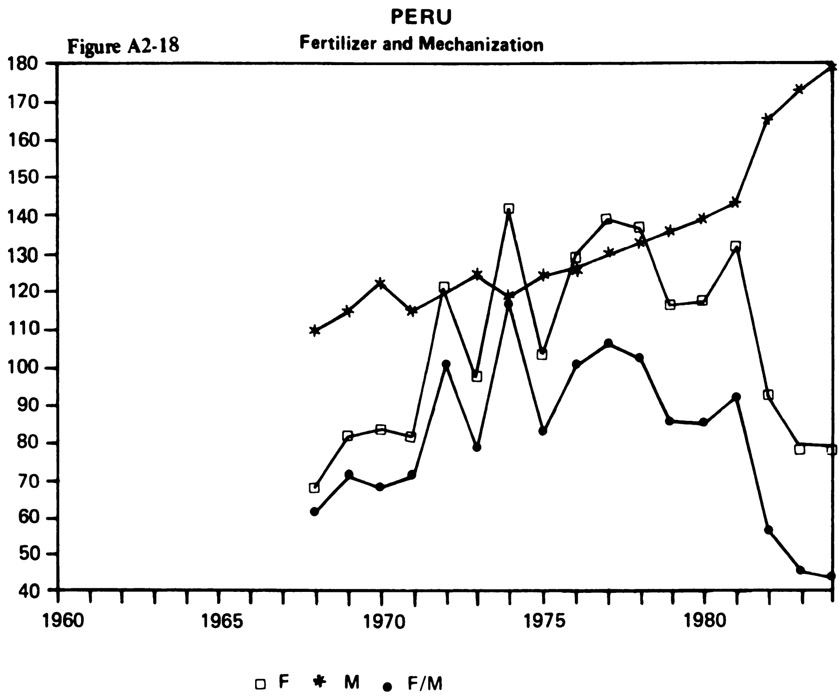


Figure A2-19

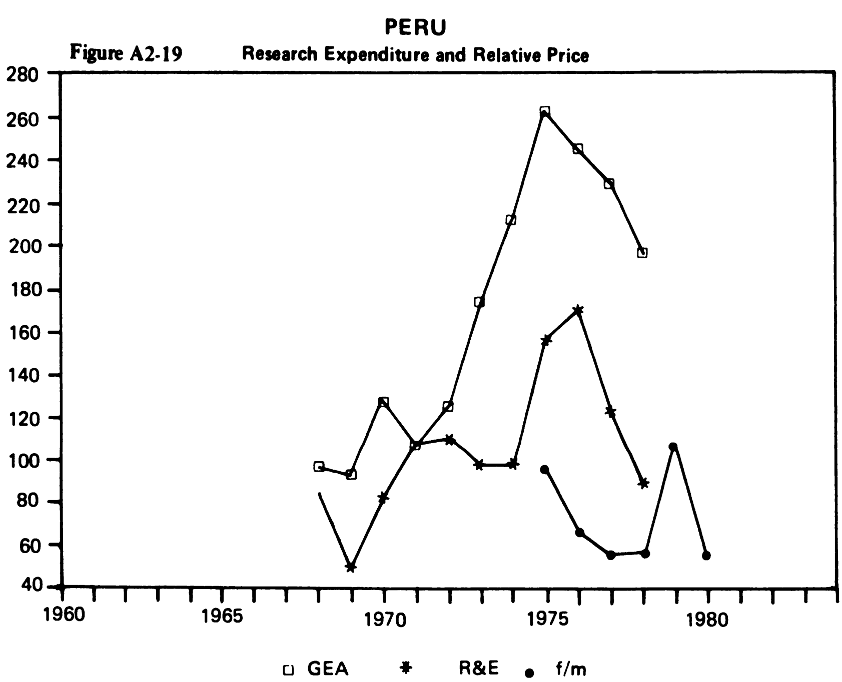


TABLE A2-11: Suriname

Years	F-FAO 1000 tons	M-FAO units	F*/M*	p Livestock	m (index)	f
1968	2					
1969	2					
1970	2					
1971	4	980	4.08			
1972	4	1 020	3.92			
1973	5	1 100	4.55			
1974	5	1 150	4.35	100	100	100
1975	3	1 180	2.54	107	112	100
1976	4	1 200	3.33	104	120	100
1977	4	1 250	3.20	114	128	100
1978	4	1 300	3.08	120	138	125
1979	2	1 350	1.48	131	151	100
1980	2	1 400	1.43		172	148
1981	6	1 450	4.14			
1982	8	1 540	5.19			
1983	13	1 590	8.18			
1984	11	1 640	6.71			

SURINAME

Figure A2-20 Fertilizer, Mechanization and Price

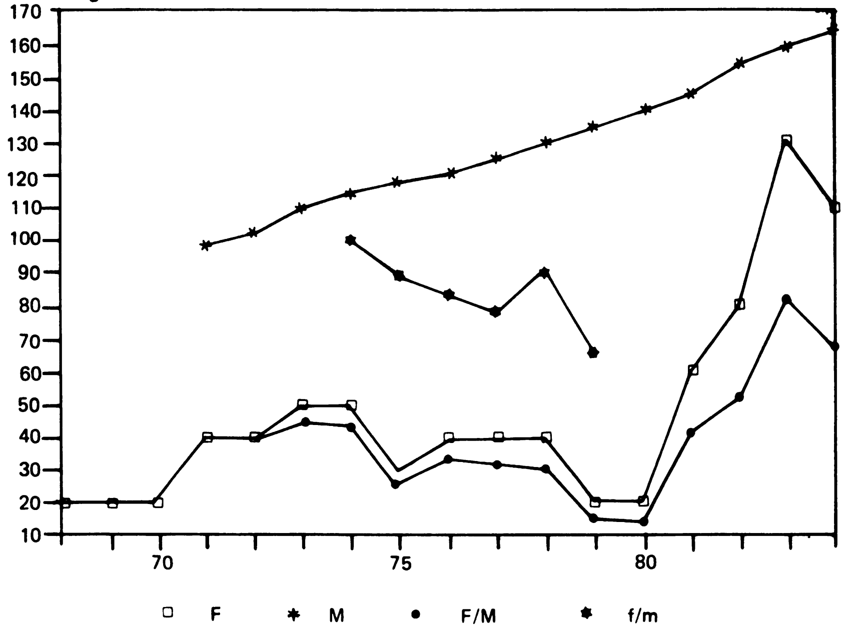
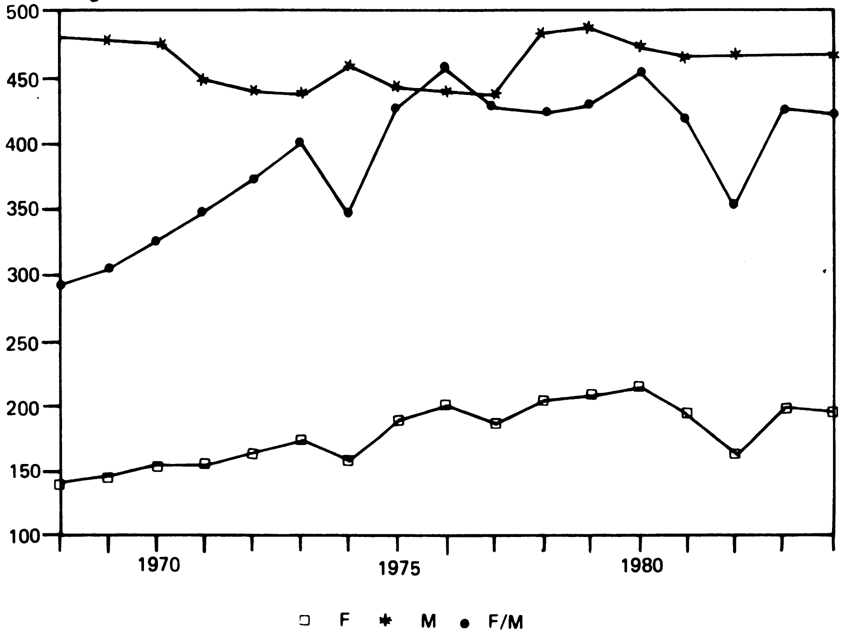


TABLE A2-12: USA

Years	F-FAO 1000 tons	M-FAO 1000 un.	F*/M* (.001)	p	m (index)	f	w S per day USDA
1968	14.1	4 810	2.93	101	105	94	10.6
1969	14.6	4 790	3.05	97	111	87	10.7
1970	15.5	4 770	3.25	100	116	88	11.1
1971	15.6	4 469	3.49	108	122	91	11.7
1972	16.3	4 387	3.72	114	128	94	13.3
1973	17.5	4 376	4.00	175	137	102	15
1974	15.9	4 585	3.47	224	161	167	16.8
1975	18.9	4 434	4.26	201	195	217	17.7
1976	20.1	4 402	4.57	195	199	184	19.5
1977	18.7	4 370	4.28	191	219	181	20.1
1978	20.5	4 839	4.24	201	239	181	22
1979	20.9	4 880	4.28	222	267	195	24
1980	21.5	4 740	4.54	239	298	242	25.7
1981	19.4	4 655	4.17	257	333	260	27.4
1982	16.4	4 669	3.51	232	362	260	29.5
1983	19.8	4 671	4.24	245	381	248	31.6
1984	19.6	4 657	4.21	266	397	259	33.8
1985				232	390	244	

USA

Figure A2-21 Fertilizer and Mechanization



USA

Figure A2-22 Relative Prices

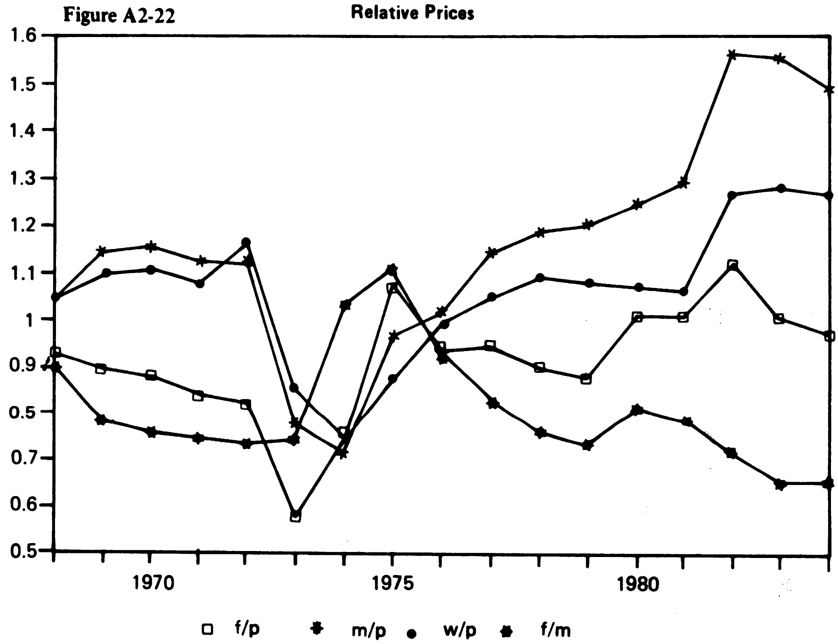
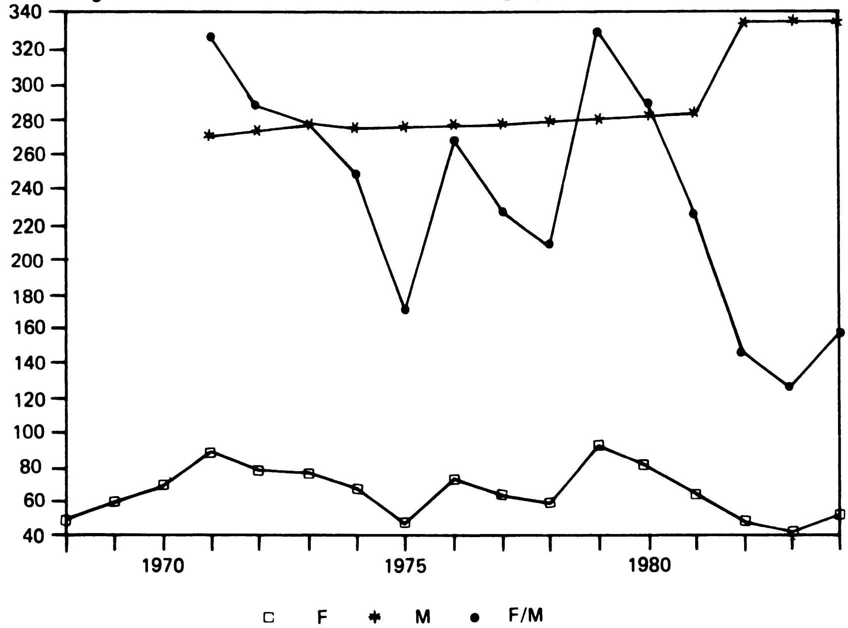


TABLE A2-13: Uruguay

Years	F-FAO 1000 tons	M-FAO 1000 un.	F*/M*	p	m (index)	f	w (LCU)	ResBud ISNAR (1000 1975 LCU)	ResBud TP (1000 1975 LCU)	ResBud/GR ISNAR (percent)
1968	49						8.1			
1969	60						12.8			
1970	69						15.6		372.3	
1971	88	27	3.26				19.6		399	
1972	78	27.3	2.86				26.9	2 983	425.7	0.287
1973	77	27.7	2.78				44.0		525.6	
1974	68	27.4	2.48	57			88.6		584.1	
1975	47	27.5	1.71	100	100	100	163.2		730.2	
1976	74	27.6	2.68	125	134	117	233.6		573.6	
1977	63	27.7	2.27	169	176	156	359.7	4 721	663.3	0.531
1978	58	27.9	2.08	307	213	214	562.4		585.3	
1979	92	28	3.29	487	291	356	859.0		773.4	
1980	81	28.2	2.87	730	384	526	1 274.3		817.8	
1981	64	28.4	2.25	832	449	633	1 636.2			
1982	49	33.5	1.46	935	553	696	1 911.5	3 499		0.37
1983	42	33.5	1.25	1 730	1 212	1 406	2 311.6			
1984	53	33.5	1.58	2 861	1 515	1 969	3 082.5			

URUGUAY

Figure A2-23 Fertilizer and Mechanization



URUGUAY

Figure A2-24 Research Expenditure and Relative Price

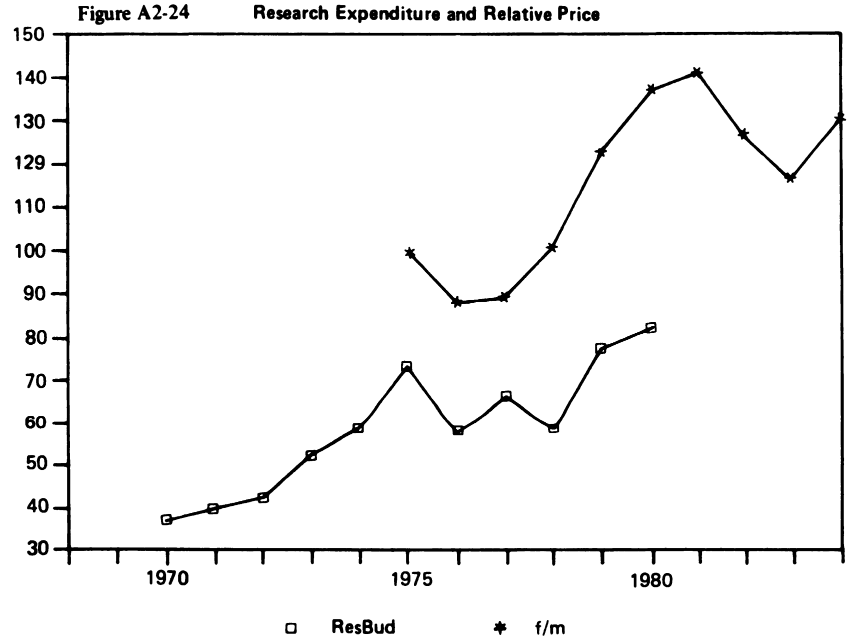
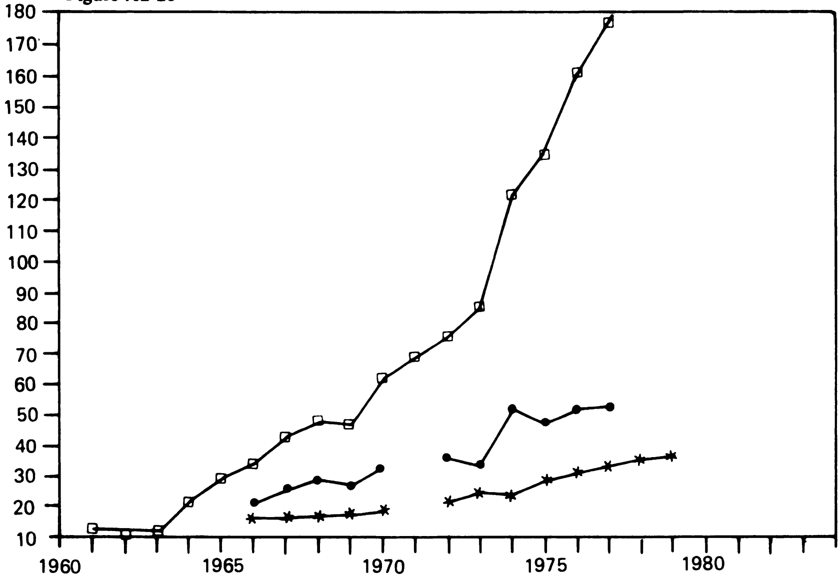


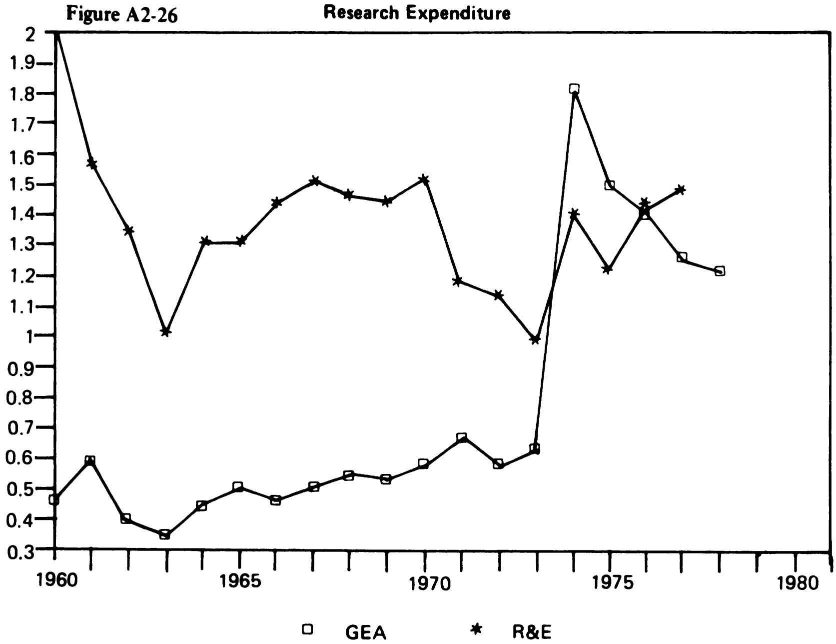
TABLE A2-14: Venezuela

Years	F Elias 1000 tons	M Elias 1000 un.	F*/M*	GEA	R&E Elias (millions 1960 LCU)	R&E stock	ResBud ISNAR (mill. 1975 LCU)	ResBud TP	ResBud/GRP ISNAR (percent)
1960				468.3	200	1 818		19.851	
1961	12.6			594.1	156.9	1 775			
1962	10.7			403.2	134.7	1 714	29.02		0.729
1963	10.7			347.8	101	1 627			
1964	21.4			445.9	131.2	1 579			
1965	29.3			505.4	131.4	1 537		31.758	
1966	33.7	16.2	2.08	467.6	144.5	1 512			
1967	43	16.6	2.59	514.2	152.7	1 499	50.05		0.926
1968	48.2	17	2.84	557	146.9	1 481			
1969	47.2	17.7	2.67	541.7	145.2	1 463			
1970	62	19.2	3.23	586.6	152.7	1 455			
1971	68.8			667.8	117.8	1 413			
1972	75.8	21.1	3.59	586.3	113.5	1 371			
1973	85.3	25.3	3.37	636.4	99.3	1 319			
1974	121.5	23.4	5.19	1 809.9	140.6	1 315			
1975	135.2	28.6	4.73	1 499.6	122.7	1 293			
1976	161	31.1	5.18	1 401.2	142.3	1 293		82.208	
1977	176.9	33.8	5.23	1 260.1	149.1	1 300	90.19	96.647	1.169
1978		35		1 219.6				99.331	
1979		37						84.387	
1980								97.7	
1981									
1982							83.37		1.007
1983									
1984									

VENEZUELA
Figure A2-25
Fertilizer and Mechanization



VENEZUELA
Figure A2-26
Research Expenditure



BIBLIOGRAPHY

ALTIERI, M.; ANDERSON, M. 1986. An ecological basis for the development of alternative agricultural systems for small farmers in the Third World. American Journal for Alternative Agriculture 1(1):30-38.

AMERICAN FROZEN FOOD INSTITUTE. s.f. Frozen food pack statistics. s.n.t.

ARROYO, G. (ed.). 1981. El desarrollo agroindustrial y la economía latinoamericana. México, CODAI, SARH.

________. 1986. La biotecnología y el análisis de las cadenas o sistemas agroalimentarios y agroindustriales. Universidad Autónoma de México. Departamento de Producción Económica y Maestría en Desarrollo Rural. Xochimilco, México.

BELL, C.; HAZELL, P.; SLADE, R. 1982. Project evaluation in regional perspective. Baltimore, The Johns Hopkins University Press. s.p.

BINSWANGER, H. 1986. Agricultural mechanization: a comparative historical perspective. World Bank Research Observer 1(1).

BUTTEL, F.H.; KENNEY, M.; KLOPPENBURG JUNIOR, J. 1985. From green revolution to biorevolution: some observations on the changing technological bases of economic transformation in the Third World. Economic Development and Cultural Change 24(1).

COMMANDER, S.; PEEK, P. 1983. Oil exports, agrarian change and the rural labor process: the Ecuadorian Sierra in the 1970's. WEP 10-6/WP63. Geneva, International Labour Organisation. p. 33.

CROFT, B.A. 1986. Keeping ahead of the wolf: pest resistance to agricultural pesticides. **In** Research for tomorrow: 1986 yearbook of agriculture. Washington, USDA. s.p.

DALRYMPLE, D. 1986a. Development and spread of high-yielding rice varieties in developing countries. Washington, D.C., Bureau of Science and Technology, Agency for International Development.

________. 1986b. Development and spread of high-yielding wheat varieties in developing countries. Washington, D.C., Bureau of Science and Technology, Agency for International Development.

DEERE, C.D.; WASSERSTROM, R. 1981. Ingreso familiar y trabajo no agrícola entre los pequeños productores de América Latina y el Caribe. **In** Agricultura de ladera en América Tropical. Turrialba, Costa Rica, CATIE.

________.; DISKIN, M. 1984. Rural poverty in El Salvador: dimensions, trends, and causes: WEP 10-6/WP64. Geneva, International Labour Organisation. p. 6.

DEERE, C.D.; JANVRY, A. DE. 1979. A conceptual framework for the empirical analysis of peasants. American Journal of Agricultural Economics 1(4):601-611.

EICHERS, T.R. 1980. The farm pesticide industry. Washington, D.C., U.S. Department of Agriculture, Economics Statistics, and Cooperative Service. (Agricultural Economics Report no. 461).

ELIAS, V. 1985. Government expenditures on agriculture and agricultural growth in Latin America. Washington, D.C., International Food Policy Research Institute. (Research Report no. 50).

ELLIOTT, H.; HERTFORD, R.; SNOW, J.; TRIGO, E. 1985. Identifying opportunities to improve agricultural management systems in Latin America: a methodology and test case. Rutgers, The State University of New Jersey.

FREDERICQ, A. 1981. La producción de leche en Brasil: el caso Nestlé. **In** El desarrollo agroindustrial y la economía latinoamericana. Ed. by G. Arroyo. México, CODAI, SARH.

FUJIMOTO, I.; KOPPER, W. 1978. Outside influence on what research gets done at a land grant school: impact of marketing orders. **In** Priorities in agricultural research of the U.S. Department of Agriculture. Part 2, Appendix (95:1). U.S. Congress. Senate Subcommittee on Administrative Practice and Procedure. Committee on the Judiciary.

GAMBLE, W.K.; TRIGO, E. 1985. Establishing agricultural research policy: problems and alternatives for small countries. **In** Agricultural research policy and organization in small countries. The Hague, Netherlands, ISNAR.

GOLDSTEIN, D.J. 1985. New patents in biotechnology: their impact on Latin America. Presented at the Planning Workshop: Biotechnology and Food Systems in Latin America (1985:San Diego). San Diego, University of California.

GONZALEZ, A.; LUZ, R.; QUINTERO R., R. 1985. El futuro alimentario y la biotecnología. Presented at the Planning Worshop: Biotechnology and Food Systems in Latin America (1985:San Diego). San Diego, University of California.

GRAU, O. 1985. Un nuevo enfoque para la cooperación regional en biotecnología: el Programa Regional Latinoamericano de Biotecnología. Presented at the Planning Workshop: Biotechnology and Food Systems in Latin America (1985:San Diego). San Diego, University of California.

HAYAMI, Y.; RUTTAN, V. 1985. Agricultural development: an international perspective. Baltimore, The Johns Hopkins University Press.

HILDEBRAND, P. 1979. Generating technologies for traditional farmers: the Guatemalan experience. **In** International Congress of Plant Protection (9, 1979, Washington, D.C.). Proceedings. Washington, D.C.

HINTERMEISTER, A. 1985. Pobreza rural y crédito agrícola al campesino. Santiago, Chile. p. 37. (PREALC/266).

HIRSCHMAN, A. 1980. Exit, voice, and loyalty: response to decline in firms, organizations, and states. Cambridge, Cambridge University Press.

________. 1981. Essays in trespassing: economics to politics and beyond. Cambridge. Cambridge University Press.

JANVRY, A. DE. 1987. International economic development and U. S. agriculture. University of Wisconsin. Department of Agricultural Economics. Madison.

________.; SADOULET, E. 1987. The conditions for compatibility between AID and trade in Agriculture. University of California. Department of Agricultural and Resource Economics. Berkeley. (Working Paper no. 430).

JUDD, M.; BOYCE, J.; EVENSON, R. 1986. Investing in agricultural supply: the determinants of agricultural research and extension investment. Economic development and cultural change.

KENNEY, M. 1986. Biotechnology: the university-industrial complex. New Haven, Yale University Press.

KLOPPENBURG, JUNIOR, J.; OTERO, G. 1985. Social impacts of biotechnology in the U.S. and the Third World. Presented at the Planning Workshop: Biotechnology and Food Systems in Latin America (1985:San Diego). San Diego, University of California.

LAJO LAZO, M. 1981. Carnation y Nestlé en el Perú. In El desarrollo agroindustrial y la economía latinoamericana. Ed. by G. Arroyo. México, CODAI, SARH.

LAKOFF, S. 1984. Biotechnology and the developing countries. Politics and the Life Sciences 2(2).

LAVE, L. 1962. Empirical estimates of technological change in U.S. agriculture, 1850-1958. Journal of Farm Economics 44(4):941-952.

LEU, GWO-JIUN, M.; SCHMITZ, A.; KNUTSON, R.D. s.f. Gains and losses of sugar program policy options. American Journal of Agricultural Economics. (Forthcoming).

LEVINS, R.; LEWONTIN, R. 1985. The political economy of agricultural research. In The dialectical biologist. Cambridge, Harvard University Press.

LOHR, L.; CARTER, H.O.; LOGAN, S.H. 1986. Agricultural biotechnology research: an overview. Davis, University of California. (Working Paper no. 86-1).

LUISELLI FERNANDEZ, C. 1986. Biotecnología y alimentación: el ámbito para la cooperación estratégica. México, CEPAL.

MALTBY, C. 1980. Report on the use of pesticides in Latin America. UNIDO/IOD.353.

MITCHELL, D. 1987. Prospects for agricultural trade and prices. In Seminar on Commercial Policies and Prices in Latin American Agriculture (1987:Cartagena, Colombia). Cartagena, Col., IICA-World Bank.

MONARDES, A. 1977. Empleo de mano de obra, producción e ingresos en predios de pequeña agricultura del valle central de Chile. Universidad de Chile. Departamento de Economía. Santiago. (Documento de Investigación no. 17).

MOONEY, P.R. 1979. Seeds of the earth: a private or public resource? Ottawa, Inter Pares.

MORALES, H.L. 1985. Biotecnologías y sistemas alimentarios. Presented at the Planning Workshop: Biotechnology and Food Systems in Latin America (1985:San Diego). San Diego, University of California.

MOULTON, K.; RUNSTEN, D. 1986. The Mexican frozen vegetable industry. Berkeley, University of California.

NEW YORK TIMES. June 8, 1987.

OBSCHATKO, E.D. DE; PIÑEIRO, M.; JACOBS, E.D. 1985. The private sector in the agricultural technological development: some conclusions and new subjects for analysis. Buenos Aires, CISEA. (PROAGRO Document no. 18).

OLSON, M. 1965. The logic of collective action. Cambridge, Cambridge University Press.

ORTEGA, E. 1982. Peasant agriculture in Latin America. CEPAL Review 16:94.

OTERO, G. 1987. From green revolution to biotechnology: impacts on U.S. and Mexican social structures. San Diego, University of California. (Center for U.S. Mexican Studies).

PIÑEIRO, M.; 1984. Technological cycles in Latin American agriculture. Buenos Aires, CISEA. (Document no. 12).

________. 1985. Agricultural research in the private sector: issues and analytical perspectives. The Hague, Netherlands, ISNAR. (PROAGRO Paper no. 1).

________.; TRIGO, E. 1985. Agricultural research in the public sector of Latin America: problems and perspectives. The hague, Netherlands, ISNAR. (Working Paper no. 1).

PIÑEIRO MACHADO, L.C. 1985. A importancia das biotecnologias para o desenvolvimento da agricultura no Brasil. Presented at the Planning Workshop: Biotechnology and Food Systems in Latin America (1985:San Diego). San Diego, University of California.

PLUCKNETT, D.L.; NIGEL, J.H.S.; HORNE, M.E. 1985. Biotechnology at the International Agricultural Research Centers in Latin America. Presented at the Planning Workshop:

Biotechnology and Food Systems in Latin America (1985:San Diego, University of California.

PROGRAMA DE LAS NACIONES UNIDAS EN DESARROLLO (PNUD). 1986. Programa Regional de Biotecnología PNUD/UNESCO/ONUDI para América Latina y el Caribe.

QUINTAR, A. 1983. Las empresas transnacionales en la agroindustria de lácteos: el caso de la Compañía Nestlé en México. Tesis de Maestría en Sociología. México, Universidad Nacional Autónoma de México.

RAMA, R.; VIGORITO, R. 1979. El complejo de frutas y legumbres en México. México, Nueva Imagen.

REPETTO, R. 1985. Paying the price: pesticide subsidies in developing countries. Washington, D.C., World Resources Institute. (Research Report no. 2).

REYES POSADA, A. 1981. La economía lechera colombiana y la empresa transnacional Nestlé. **In** El desarrollo agroindustrial y la economía latinoamericana. Ed. by G. Arroyo. México, CODAI, SARH.

RIGGS, L.A. 1985. The biotechnology industry in California and the U.S.: Characteristics and progress. Presented at the Planning Workshop: Biotechnology and Food Systems in Latin America (1985:San Diego). San Diego, University of California.

ROCA, W.M.; AMEZQUITA, M.C.; VILLALOBOS, V.M. 1986. Estado actual y perspectivas de la biotecnología agrícola en América Latina y el Caribe. Encuesta 1986. **In** Seminario Internacional sobre Temas Prioritarios y Mecanismos de Cooperación en Investigación Agropecuaria en América Latina y el Caribe (1986, Cali, Colombia). Cali, CIAT.

RUTTAN, V. 1983. Agricultural research policy. Minneapolis, University of Minnesota Press.

SAMPER, A. 1982. La investigación privada en Colombia. Cali, Colombia, CENICAÑA.

SAN FRANCISCO EXAMINER, June, 1987.

SCANDIZZO, P. 1984. Agricultural growth and factor productivity in developing countries. Rome, FAO, United National. (Economic and Social Development Paper no. 42).

SCHACHT, H. 1987. Exotic trends in the produce fields. San Francisco Chronicle.

SCHULTZ, T.W. 1964. Transforming traditional agriculture. New Haven, Connecticut, Yale University Press.

SCOBIE, G.; POSADA, R. 1977. The impact of high-yielding rice varieties in Latin America with special emphasis on Colombia. Cali, Colombia, CIAT. (Series JE-01).

SILVA, E. DA. 1983. Peasant production, labor reserve, and the food economics of northeast Brazil. University of California. Department of Agricultural and Resource Economics. Berkeley.

TRIGO, E.; PIÑEIRO, M. 1981. The dynamics of agricultural research organizations in Latin America. Food Policy 6:2-10.

_______ ; PIÑEIRO, M.; SABATO, J. 1983. La cuestión tecnológica y la organización de la investigación agropecuaria en América Latina. Desarrollo Económico 23(89).

U.S. CONGRESS. OFFICE OF TECHNOLOGY ASSESSMENT. 1987. Technology, public policy, and the changing structure of American agriculture. Washington, D.C. (OTA-F-285).

U.S. DEPARTMENT OF AGRICULTURE. s.f. Agricultural statistics. California Strawberry Processing Advisory Board, 1985-1986. Washington, D.C.

U.S. DEPARTMENT OF COMMERCE. s.f. Bureau of the census. U.S. Import for Consumption. Washington, D.C.

U.S. DEPARTMENT OF COMMERCE. s.f. Bureau of the census. U.S. Imports for Consumption. Washington, D.C. (Schedule E and FAS reports).

UNION NACIONAL DE PRODUCTORES DE HORTALIZAS AND FAS REPORTS.

UNITED NATIONS. FAO. 1986. Background paper on the food and agricultural situation in Latin America and the Caribbean. Rome. (LARC/86/INF/4).

_______. s.f. Production Yearbooks and trade yearbooks; conversion factors from U.S. Department of Agriculture. Agricultural Statistics.

VALDES, A. 1984. Trade in agricultural products between developing countries: Latin American exports during 1962-1979. Materie Prime 13(2):97-107.

VIGORITO, R.; SUAREZ, B. 1981. Capital extranjero y complejos agroalimentarios en América Latina: historia y estrategias. México, Instituto Latinoamericano de Estudios Transnacionales.

VINIEGRA GONZALEZ, G. 1985. Modern scientific research and traditional production processes. Selected case studies in Mexico. Presented at the Planning Workshop: Biotechnology and Food Systems in Latin America (1985:San Diego). San Diego, University of California.

WAISSBLUTH, M.; CADENA, G.; SOLLEIRO, J.L. 1985. La vinculación Universidad/Industria: una experiencia organizacional en México. Presented at the Planning Workshop: Biotechnology and Food Systems in Latin America (1985:San Diego). San Diego, University of California.

WILLIAMS, S.; KAREN, R. 1985. Agribusiness and the small-scale farmer. Boulder, Westview Press.

WEIR, D.; SHAPIRO, M. 1981. The circle of poison. San Francisco, Institute for Food and Development Policy.

WRIGHT, A. 1986. Rethinking the circle of poison: the politics of pesticide poisoning among Mexican farmworkers. Latin American Perspectives 13(4).

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PROGRAM II: Technology Generation and Transfer

The Technology Generation and Transfer Program was created in response to two basic issues: acknowledgement by the countries and the international technical and financial community of the importance of technology for productive development of the agricultural sector; the widespread belief that the potential of science and technology can fully be tapped only in the presence of institutional infrastructures capable of developing technical responses to the specific conditions of each country, and a framework of policies which will encourage and facilitate the incorporation of new technology into production processes.

In this context, Program II will promote and support actions in the member countries to improve technological policy design, strengthen the organization and management of their technology generation and transfer systems, and facilitate international technology transfer. This should lead the way to better use of available resources and a more effective contribution to solving technological problems in agricultural production, within a framework of equitable distribution of benefits and conservation of natural resources.

According to the 1987-1991 Medium Term Plan, the Technology Generation and Transfer Program will concentrate its activities to tackle these problems through actions in five basic areas:

- Technological policy design.
- Organization and management of national technology generation and transfer systems and institutions.
- Development and/or strengthening of human resource training programs.
- Reciprocal cooperation and international coordination of research and technology transfer.
- Formulation and implementation of investment projects.

Program II pursues its primary objective by confronting several factors which hinder and limit agricultural development and rural well-being in the countries of the region. First, technological policy must be linked to other aspects of agrarian policy. Moreover, it is imperative to strengthen the organization and budgets of technological institutions, consolidate duly trained human resources, and integrate research, teaching and technology transfer. Special focus is placed on a problem faced by small countries, where there is a serious gap between the need for technological development and the amount of resources which can be invested therein.

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