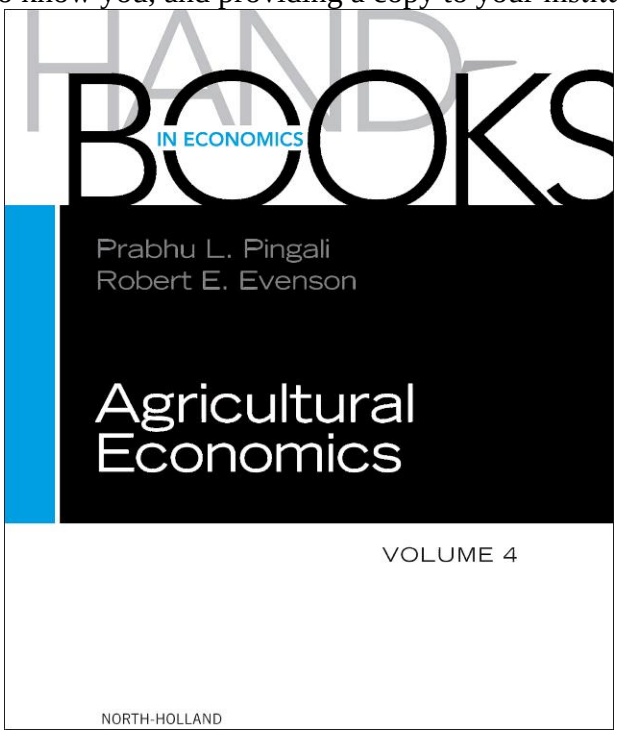

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CHAPTER 71

Agricultural Productivity in Latin America and the Caribbean and Sources of Growth

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Contents

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Abstract

Agricultural productivity in the Latin American and Caribbean (LAC) countries between 1961 and 2001 increased due to market regulation, economic openness, and estate reduction. In the six major sections of this chapter, we analyze the evolution of this productivity as well as the output and input growth for the agricultural and livestock sectors. We look closely at economic indicators related to food demand and population growth as well as total factor productivity growth for the region, with an emphasis on the Brazilian and Colombian agricultural sectors. We also discuss some sources of productivity growth, highlighting agricultural research, rural extension, schooling, and nutrition, and ultimately review income improvement and poverty reduction studies.

JEL classifications: Q15, Q18, J43, E61

Keywords

agricultural productivity
food demand
population growth
poverty reduction

1. INTRODUCTION

To face secular problems concerning inflation, underemployment, poverty, and fiscal deficits, during recent decades Latin American and Caribbean (LAC) countries implemented "structural adjustment" policies such as market deregulation, economic openness, and estate reduction. Consequently, the region experienced considerable economic and institutional transformation in its agricultural sector in terms of production, productivity, competitiveness, and profitability. In addition, the structural adjustment processes that have been carried out have led to a reallocation of fiscal resources, since they are now focused to provide basic services (health, education, and security, among others). The remaining resources to support agricultural activities such as science and technology, irrigation, price support, and subsidies to credit have decreased, especially in the Andean countries (IICA, 1999).

In this chapter, we analyze this evolution of agricultural productivity from 1961 to 2001, calculating partial and total productivity indexes by region (Southern Cone, Andean, Central America, and Caribbean) and their countries and for the LAC as a whole.

In Section 2 we analyze the output and input growth for the agricultural and livestock sectors. The section also includes an analysis of some regional productivity

indicators based on the World Bank database. This section is completed with an analysis of some partial productivity indexes such as labor and land productivity, fertilizer, and machinery per hectare and agricultural capital per worker.

Section 3 presents some economic indicators related to food demand and population growth according to IFPRI projections, average and rate of growth of GDP per capita, birth, mortality, and child mortality based on Economic Commission for Latin America and the Caribbean (ECLAC) estimations.

Total factor productivity growth for the LAC region is analyzed in Section 4, with emphasis on the Brazilian and Colombian agricultural sectors. A synthesis of the other TFP studies developed in the region is presented in the same section. In the analysis we compare these results with the recent estimations of TFP for the region developed by Evenson and Avila (2003) based on the FAO statistical database. The paper also presents an analysis of the regional diversity in terms of agroecological zones.

In Section 5 we discuss some sources of productivity growth, with emphasis on agricultural research, rural extension, schooling, and nutrition. The LAC research intensity is analyzed by country and subregion and is compared with research indicators from other world regions. We also include an analysis of the determinants of TFP in LAC.

Section 6 is concerned with income improvement and poverty reduction studies based on several ECLAC documents.

Finally, Section 7 is devoted to conclusions.

2. AGRICULTURAL INDICATORS

2.1 Crop area yield accounting

Table 1 presents the rates of growth for LAC and by each one of its regions and their countries for two periods: 1962–1981 and 1982–2001. In general, only the Caribbean region presents a poor performance of the agricultural sector in terms of annual growth, with 0.60% in the period. The other three LAC regions experienced annual rates of growth superior to 2.5%. The annual average rate of output growth for the entire region was 2.31%.

If we analyze the LAC countries individually, Costa Rica, Bolivia, and Brazil present the highest rates of growth in output during the period. At the other extreme, we have all the Caribbean countries with poor rates of growth in agriculture. The poorest performance was in Cuba, where the agricultural output decreased substantially in the recent period (1982–2001). Uruguay had also a low rate of growth, but it was basically influenced by poor performance of the livestock sector.

The rates of growth for land for the LAC regions are presented in Table 2. The table includes rates of growth for cropland and permanent pastureland and for the aggregate. Comparing the two periods of analysis, the rates of growth for agricultural land (crops and livestock) are decreasing in the Southern Cone, Andean, and Caribbean regions

Table 1 Latin American and Caribbean agricultural output growth rates (%), 1962–2001

Regions/ Countries	Crops			Livestock			Average Growth		
	1962–1981	1982–2001	Average	1962–1981	1982–2001	Average	1962–1981	1982–2001	Average
Southern Cone	2.79	2.98	2.89	1.74	2.95	2.34	2.27	2.96	2.62
Andean	2.43	2.65	2.54	3.95	2.92	3.44	3.19	2.79	2.99
Central America	3.60	1.32	2.46	4.35	2.84	3.59	3.97	2.08	3.03
Caribbean	1.20	−0.71	0.24	2.78	0.77	1.78	1.99	0.03	0.60
Average rate	2.55	1.57	2.06	3.56	2.38	2.97	3.05	1.98	2.51

Source: FAO agricultural data; FAOSTAT (agricultural production indices).

Table 2 Latin American and Caribbean agricultural land growth rates (%), 1961–2000

Regions/ Countries	Crop Land			Permanent Pastures			Average Growth		
	1961–1980	1981–2000	Average	1961–1980	1981–2000	Average	1961–1980	1981–2000	Average
Southern Cone	1.79	−0.14	0.82	0.81	0.39	0.60	1.30	0.12	0.71
Andean	1.04	−0.06	0.49	0.92	0.30	0.61	0.98	0.12	0.55
Central America	0.47	0.90	0.68	1.08	0.95	1.02	0.77	0.92	0.85
Caribbean	1.43	0.78	1.10	−0.02	−0.47	−0.24	0.71	0.15	0.43
LAC average	1.18	0.43	0.80	0.92	0.35	0.64	1.05	0.39	0.72

but are increasing in Central America. At the country level, the reduction in the cropped area was more important in Chile, Uruguay, Colombia, and Jamaica, which presented an average negative rate of growth. On the contrary, we see Brazil, Paraguay, Ecuador, Costa Rica, Nicaragua, Guatemala, and Trinidad and Tobago presenting higher rates of growth (more than 1%).

Using the rates of growth for the crops and livestock output and for land, we calculated the yield accounting for crops, livestock, and aggregate, presented in Table 3. The yield accounting results also indicate that in the Caribbean region the productivity of the agricultural sector is decreasing. The other LAC regions perform very well, especially the Andean region and the Southern Cone.

At the country level, we had good performance in the first period (1961–1980) in the case of Bolivia, Venezuela, Mexico, Guatemala, Honduras, and Panama. However, these rates of growth were not uniform, considering the two sectors analyzed (crops and livestock). In general, this good performance was due to the livestock sector, except for Guatemala.

During the 1980s and 1990s, the productivity growth rates were again good for Bolivia and Honduras but also high for other countries (Chile, Brazil, Argentina, Ecuador, and Costa Rica). The rate of growth for crops was better for Chile, Bolivia, Argentina, and Costa Rica and good for livestock in Brazil, Ecuador, Peru, Dominican Republic, and Honduras. Chile also performed very well in livestock.

2.2 Input productivity and cereal yields

Based on some World Bank indicators for the agricultural sector, presented in Table 4, we can verify that the LAC regions, except the Caribbean, improved the performance in cereal yields, agricultural productivity, and fertilizer consumption from the final years of the 1970s and beginning of the 1980s to recent years. These results are consistent with all the calculations shown previously.

Table 3 Latin American and Caribbean agricultural area yield accounting (%), 1962–2001

Regions/ Countries	Crops			Livestock			Aggregate		
	1962–1981	1982–2001	Average	1962–1981	1982–2001	Average	1962–1981	1982–2001	Average
Southern Cone	1.01	3.12	2.06	0.93	2.56	1.74	0.97	2.84	1.90
Andean	1.39	2.71	2.05	3.03	2.63	2.83	2.21	2.67	2.44
Central America	3.13	0.42	1.78	3.27	1.89	2.58	3.20	1.16	2.18
Caribbean	−0.23	−1.49	−0.86	2.80	1.24	2.02	1.28	−0.12	0.58
LAC average	1.37	1.15	1.26	2.64	2.03	2.33	2.00	1.59	1.80

Table 4 Latin American and Caribbean World Bank agricultural indicators by region, 1979–2000

Regions/ Countries	Cereal Yield (kg/Ha)		Agricultural Productivity (Agricultural Value Added/Wk)		Fertilizer Consumption (100 kg/Ha Arable Land)	
	1979–1981	1998–2000	1979–1981	1998–2000	1979–1981	1997–1999
Southern Cone	1797	3264	4138	6494	381	1016
Andean	1824	2533	2362	2618	480	1088
Central America	1730	2146	1864	2319	938	2008
Caribbean	2265	2205	1723	1737	991	806
LAC average	1904	2537	2522	3292	698	1230

2.3 Agricultural technology adoption

According to Evenson (2003), in Latin America the rate of growth in the adoption of modern varieties was very high during the last 30 years (Table 5). This rate of growth was more impressive during the 1980s, especially in the case of wheat, maize, rice, and potatoes. For beans and cassava these rates of growth are still relatively small.

Table 5 Adoption of modern varieties in the main crops cultivated in Latin America (% of area planted to modern varieties), 1970–2000

Crop	1970	1980	1990	2000
Wheat	11	46	82	90
Rice	2	22	52	65
Maize	10	20	30	46
Beans	1	2	15	20
Cassava	0	1	2	7
Potatoes	25	54	69	84
All crops	8	23	39	52

Source: Evenson, R. E., "Production Impacts of Crop Genetic Improvement." In: Evenson, R. E., and Gollin, D. (eds.), *Crop Variety Improvement and Its Effect on Productivity: The Impact of International Agricultural Research*, CABI Publishing, Wallingford, U.K., Chapter 20, pp. 409–25.

The aggregated rate of adoption considering all Latin American crops also presented a high rate of growth (from 8–52% of the cropped area). When we desegregate these adoption rates by LAC subregion, the Southern Cone presents better performance. For this subregion it is estimated that 75% of the agricultural cropped area uses modern varieties. This rate of adoption is 64% in the Andean region and 45% in Central America. In the Caribbean this adoption rate is around 40%.

3. ECONOMIC INDICATORS

3.1 Food demand and population growth

According to the International Model of Policy Analysis of Commodities and Trade (IFPRI), under the most likely scenario global demand for cereal will increase 39% from 1995–2020, reaching 2466 millions tons; demand for meat is expected to increase 58%, and demand for roots and tubers, 37% (Pinstrup-Andersen et al., 1999).

Almost all the increase in food demand will take place in developing countries, since they will account for about 85% of the 690 million tons of increase in global demand for cereals between 1995 and 2020. Of this amount, LAC will represent 10.6%. In the case of meat products, LAC will participate with 16.4% of the total demand, and roots and tubers with 9.9% (Pinstrup-Andersen et al., 1999).

These large increases in food demand will result from population growth as well as urbanization, income growth, and changes in lifestyles and food preferences.

Regarding population and based on the "World Population Prospect" (UN, 1999), the world's population will grow by 1836 million from 1995–2020 (see Table 1), an increase of 32.4%. In this picture, LAC countries will increase their population levels from 480 million to 665 million in 25 years, an increase of 38.5%. LAC countries will contribute 10% of the world's population increase during this period. Table 6 reports population estimates for 1995 and 2020.

In addition, by 2020 about 52% of the developing countries' population will be living in urban areas, up from 38% in 1995 (UN, *op. cit.*). In the case of LAC, the population living in urban areas will represent 83% of the total population (Sànchez-Griñan, 1998). This rapid urbanization will have significant effects on food preferences and hence on demand, since people in urban areas tend to consume more livestock products, fruits, vegetables, and processed foods and lesser amounts of coarse grains.

From the demand side, even though most LAC people get enough food to meet their caloric requirements, 15% of the population is still underfed (Garret, 1995). Related to the supply side, urbanization, as mentioned, is carrying significant changes in the structure of food demand, but this in turn will have important effects on the structure of agricultural production and technology development to face these mentioned changes (Trigo, 1995). As an example of the challenges to come, according to

Table 6 World population (M), 1995 and 2020

World Regions	Population Level		Population increase		Share of Pop. increase
	1995	2020	1995–2020		
	Millions		Millions	Percent	Percent
Latin America and the Caribbean	480	665	185	38.5	10.1
Africa	697	1187	490	70.3	26.7
Asia, excluding Japan	3311	4421	1110	33.5	60.5
China	1221	1454	233	19.1	12.7
India	934	1272	338	36.2	18.4
Developed countries	1172	1217	45	3.8	2.5
Developing countries	4495	6285	1790	39.8	97.5
World	5666	7502	1836	32.4	100.0

Source: United Nations, *World Population Prospect: The 1998 Revision*. New York: UN, 1999.

the estimations of IFPRI, a modest expansion in cereal area is forecast in LAC, so important crop yield will be required to obtain the necessary production increase.

On the other hand, the population figures of each LAC country presented in Appendix 1 for the years 1980 and 2000 show different patterns of growth: Although the representative countries of the Caribbean (Jamaica, Trinidad and Tobago, and Cuba) and the Southern Cone, with the exception of Paraguay, had the lowest population growth rates from 1980 to 2000, the highest correspond to Andean and Central America countries.

3.2 LAC GDP per capita

Table 7 presents the annual growth of GDP per capita by region of Latin America and the Caribbean, by period of analysis.

The best performance is presented by the Southern Cone region in the two periods. In general, overall the LAC regions had a good GDP per capita performance during the first period (2.6%) but very poor results during the 1980–2001 period. In the second period, only the Southern Cone presented a good rate, but it was basically due to the excellent performance of the Chilean economy, with a GDP growth rate of 4.72%.

Table 7 Latin America and the Caribbean GDP per capita and growth rate (*), 1961–2001

Region/ Countries	Average GDP, 1961–1980**	Rate of Growth, 1961–1980 (%)	Average GDP, 1981–2001	Rate of Growth, 1981–2001 (%)
Southern Cone	3389	3.17	4440	2.11
Argentina	6619	1.98	7151	1.04
Brazil	2751	5.10	4235	0.86
Chile	2268	0.74	3750	4.72
Paraguay	1186	3.46	1794	−0.13
Uruguay	4121	1.39	5271	1.96
Andean	1995	2.50	2059	0.29
Bolivia	951	1.02	887	0.45
Colombia	1439	2.84	2134	1.47
Ecuador	1065	4.25	1506	0.02
Peru	2361	1.36	2266	−0.48
Venezuela	4159	0.55	3501	−0.28
Central America	1638	2.30	1932	0.49
Costa Rica	2465	3.09	3165	2.02
El Salvador	1657	1.40	1500	1.74
Guatemala	1244	2.92	1432	0.54
Honduras	613	1.98	699	0.22
Mexico	2355	3.23	3320	0.62
Nicaragua	860	0.61	497	−2.52
Panama	2270	2.91	2911	0.82
Caribbean	1663	2.43	2161	0.12
Dominican Republic	956	4.13	1543	2.14
Haiti	517	0.47	451	−2.71
Jamaica	2169	1.22	2107	0.87

Continued

Table 7 Latin America and the Caribbean GDP per capita and growth rate (*), 1961–2001—Cont'd

Region/ Countries	Average GDP, 1961–1980**	Rate of Growth, 1961–1980 (%)	Average GDP, 1981–2001	Rate of Growth, 1981–2001 (%)
Trinidad and Tobago	3008	3.91	4542	0.17
LAC	2144	2.60	2603	0.75

*Weighted by cropped area.
**Constant 1995 US$ prices.

3.3 Birth and death rates

In the following sections we analyze the evolution of the death and birth rates during the 1960–2005 period in the LAC subregions: Southern Cone, Andean, Central America, and the Caribbean. The information was taken from ECLAC-CELADE (2004).

3.3.1 Birth rates

Figure 1 shows a strong decrease in the crude birth rates (per thousand) in all the four subregions and for LAC as a whole. The average birth rates reduced from 41.1 in the 1960–1965 period to 22.0 in 2000–2005. Actually, these rates are very similar in the Southern Cone, Central America, and the Caribbean (around 20) and a little higher in the Andean region. The worst performances in this indicator are those of Bolivia, Guatemala, Honduras, Nicaragua, and Haiti, with indexes superior to 30. The best performance is observed in Chile, Uruguay, Cuba, and Trinidad and Tobago.

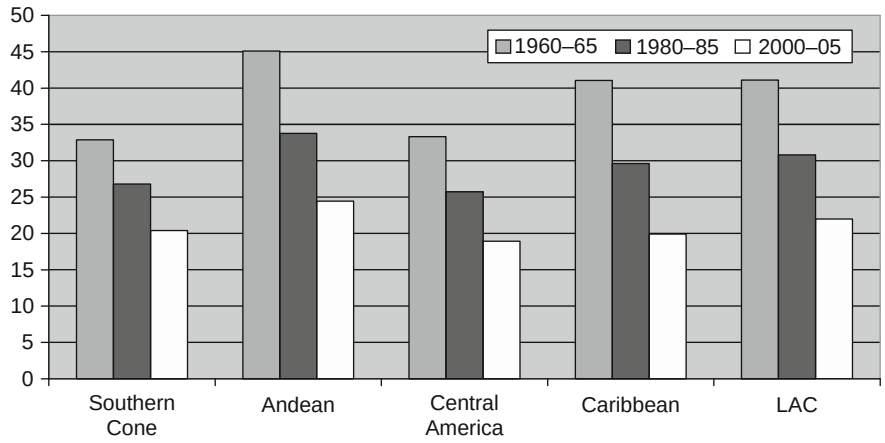

Figure 1 Birth rates in Latin American and Caribbean countries, 1960–2005.

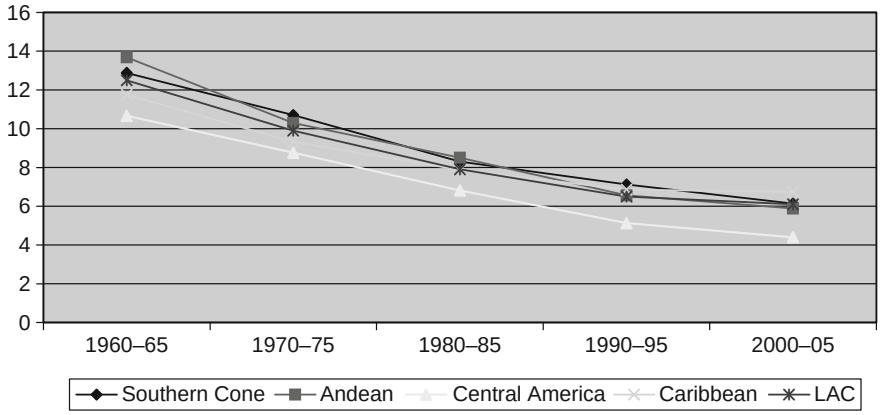

Figure 2 Mortality rates in Latin America and the Caribbean region, 1960–2005.

3.3.2 Mortality rates

The situation of the LAC countries in regard to the crude mortality rates are also decreasing. The crude mortality rates per thousand were reduced more than 50% during the last 40 years. The average rate was 12.5% in 1960–1965 and now is close to 6%. Uruguay is also the leader in this indicator. The worst indexes are observed in Brazil, Argentina, Bolivia, Costa Rica, Jamaica, and the Dominican Republic.

3.4 Infant mortality rates

The infant mortality rates for Latin America are shown in Figure 3. This indicator presented excellent performance during the period of analysis, with a decrease of more than three times (108 in 1960–1965 against 28 in 2000–2005).

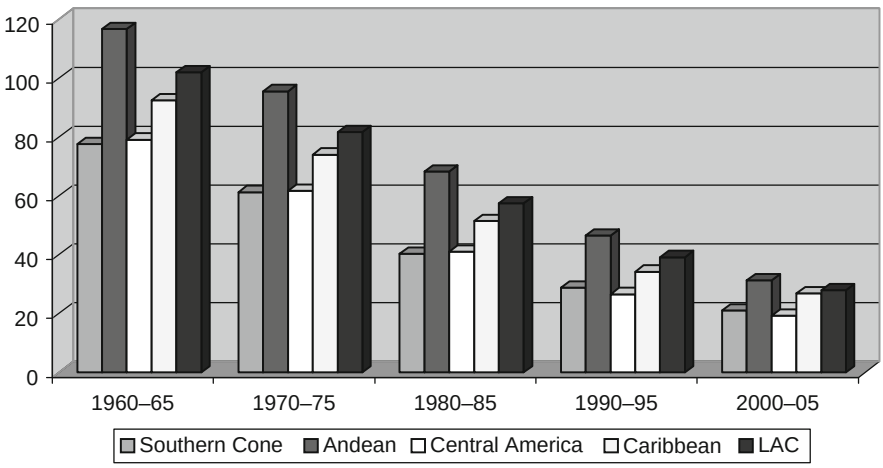

Figure 3 Infant mortality in LAC (per thousand), 1960–2005.

4. AGRICULTURAL TFP MEASURES IN LAC

This section presents an overview of the agricultural TFP studies in Latin America and the Caribbean, with emphasis on two countries, Brazil and Colombia, one located in the Southern Cone and other in the Andean region but both with an agricultural sector very important to the economy. The new agricultural TFP calculations presented in this section are an update of previous studies developed by Avila and Evenson (1995) and Romano (1987), respectively, for Brazil and Colombia. The section is completed with regional TFP indexes using FAO data (Evenson and Avila, 2004) and a review of the main TFP studies developed in Latin America.

4.1 TFP measures: Country studies

4.1.1 Brazil

Methodology The Brazilian study is based on the definition of TFP that is derived from a cost-accounting framework, which allows us to define a change in TFP from period $t-1$ to period t. Changes from period to period can then be summed up to create TFP measures when we have more than two periods. If no extraordinary profits exist and returns to all factors are properly measured, the

$$\sum_i P_i Y_i = \sum_j R_j X_j \tag{1}$$

values of all outputs (Y_i) will equal the value of all inputs (X_i).

Expression (1) does not impose strict efficiency by all farmers. It is based on an accounting condition that holds in a competitive sector.

Differentiating (1) totally with respect to time, we obtain the following expression:

$$\sum_i P_i \frac{\partial Y_i}{\partial t} dt + \sum_i Y_i \frac{\partial P_i}{\partial t} dt = \sum_J R_J \frac{\partial X_J}{\partial t} dt + \sum_J X_J \frac{\partial R_J}{\partial t} dt \tag{2}$$

For small changes, (2) expresses the relationship between changes in output and input quantities and output and input prices.

As demonstrated by Avila and Evenson (1995), the Tornqvist-Theil TFP index for multiple periods in logarithmic form is:

$$ln\,(TFP_t/TFP_{t-1}) = \frac{1}{2}\sum_i (S_{it} + S_{it-1}) ln\,(Y_{it} + Y_{it-1}) - \frac{1}{2}\sum_j (C_{jt} + C_{jt-1}) ln\,(X_{jt} + X_{jt-1})$$

We construct TFP indexes for each census micro-region based on data from the 1970, 1975, 1985, and 1995 Censuses of Agriculture for Brazil. For each micro-region, the Tornqvist-Theil index is computed for the three-period changes 1975–1970, 1985–1975, and 1995–1985. These are normalized to an index = 100 for the 1970–1975 averages period.

Output index The output index was constructed using the following products: (1) temporary crops: wheat, rice, beans, maize, soybeans, cotton, manioc, onion, and tomato; (2) permanent crops: cocoa, coffee, sugar cane, apples, guaraná, cashew, rubber, banana, citrus, and grapes; and (3) livestock: beef cattle, milk, poultry, swine, wool, and eggs.

Input index The input index was constructed using the following agricultural production factors: (1) crops: cultivated area, labor force (permanent, family, and temporary), tractors, animal power, fertilizer, and chemicals; and (2) livestock: natural and artificial pastures, labor force (permanent, family, and temporary), tractors, fertilizers, chemicals, feed, and animal medicines. In both cases, the prices used were collected from each one of the agricultural census years or from secondary sources.

Total factor productivity: Brazil and regions Table 8 presents the TFP index for each of the five geographical Brazilian regions and for the country as a whole. These estimates were calculated based on the agricultural census data for the 1970, 1975, 1985, and 1995 periods.

The results presented in Table 8 are very consistent with the recent developments in Brazilian agriculture for the two sectors (crops and livestock) and for the aggregate. These results are also consistent with those obtained for other authors, such as Avila and Evenson (1995) and Gasquez and Conceição (2001).

The annual rates of growth in the period 1970–1995, not only for crops and livestock but for Brazil as a whole, increased 3.5% per year.

The results by region also show consistent rates of growth, with bigger TFP rates in the Center-West region, exactly the region where new arable and permanent pastures were incorporated into the production system in the last two decades. In this region the state with the best rate of growth in TFP was Mato Grosso.

Table 8 shows that besides the Center-West, the North and Northeast regions present a good performance on for crops due to the expansion of the agricultural frontier in these two regions, especially in Rondônia's State (North) and Maranhão and Piaui's States (Northeast). However, is important to note that the traditional Brazilian regions located in the Southeast and South of the country also presented good rates of growth in TFP for crops. For livestock, the better performance is again in the Center-West region, followed by the Southeast. Northeast, the poorest Brazilian region, and South,

Table 8 Agricultural TFP index and rates of growth (%) by Brazilian region, 1970–1995

Region	Sector	1970 Index	1995 Index	Growth Rate (%)
North	Crops	101.35	179.00	4.72
	Livestock	86.71	135.84	−1.33
	Aggregate	95.70	168.10	0.89
Northeast	Crops	95.60	202.08	3.04
	Livestock	80.41	77,01	−0.16
	Aggregate	86.47	130.56	1.66
Southeast	Crops	100.88	169.88	2.11
	Livestock	74.27	116.58	1.82
	Aggregate	83.91	166.06	2.77
South	Crops	86.24	157.14	2.43
	Livestock	83.79	93.48	0.44
	Aggregate	85.43	140.84	2.02
Center-West	Crops	101.99	293.89	4.32
	Livestock	82.24	158.52	2.66
	Aggregate	87.22	215.83	3.69
Brazil	Crops	94.32	269.68	4.29
	Livestock	81.46	115.74	1.41
	Aggregate	87.89	209.54	3.54

a traditional beef cattle producer, presented the lowest rates of growth in TFP for livestock. The rates of growth in the TFP for livestock in the South were not worst because in this region we had in the last decades a very good development of the swine and poultry production.

TFP by Brazilian agroecological zones Figure 4 presents the main Brazilian agroecological zones, elaborated by the Embrapa Soil Research Center. In this figure four macro zones—crops (yellow), extractive (brown), livestock (red), and preservation (green)—are shown. Table 9 presents TFP growth rates for these macro agroecological zones.

As expected, in the estimates the macro zones more oriented for crops perform better (at an aggregate TFP annual growth rate of 2.28%) than the other macro zones (livestock and extractive). This macro zone includes the majority Center-South of Brazil and the Cerrados region, the new agricultural frontier of the country. At the

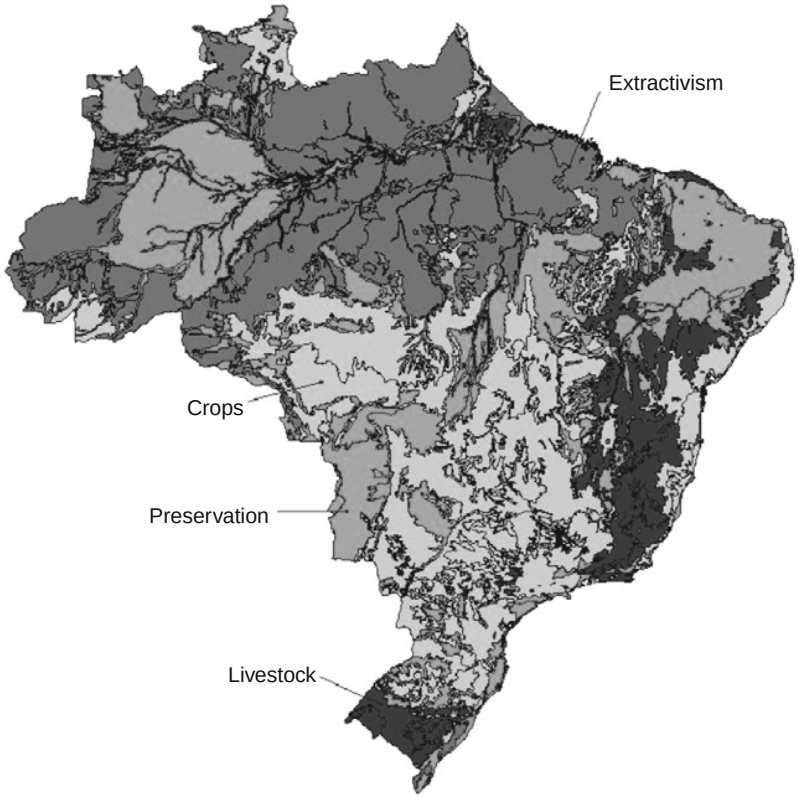

Figure 4 Brazilian agroecological zones (Embrapa Soil), 1993.

Table 9 TFP by Brazilian macro agroecological zones, 1970–1995

Agroecological Zone	Aggregated Index				Rate of Growth (%)
	1970	1975	1985	1995	
Crops	85.85	114.14	134.17	150.84	2.28
Extractive	95.90	104.10	112.40	141.26	1.56
Livestock	85.66	114.34	125.26	127.59	1.61
Preservation	91.55	108.45	104.99	119.16	1.06

other extreme, the macro zone classified by Embrapa as preservation, involving the majority of the municipalities in the Amazon, semi-arid, "pantanal," and coastal tablelands regions, presented the smaller aggregate TFP index (1.06%).

4.1.2 Colombia

Methodology In the Colombian TFP study developed for the 1960–2001 period (Romano, 2003), we used a chain-linked variable weight (Divisia type index) with a Tornquist approximation; current prices are used as a base for each year in succession, and the year-to-year rates of growth are linked with a chain index. All calculations are performed in real terms (1970 = 100).

The variables used to calculate the TFP are the following:

O = Gross value of crops and livestock in each year.
L = Labor; the total number of man-days employed in crop and livestock production per year.

instead of working with an aggregate capital variable. The capital variable is divided into selected categories as follows:

A = Land as hectares of cropped and pasture land per year.
I = Intermediate purchased inputs used in production of crops and livestock (seed, fertilizers, concentrates, pesticides, etc.) measured in monetary value per year.
S = Stock of inventory of machinery, livestock, and land improvements.

Partial Productivities

Input Growth According to Table 10, during the period 1991–2001 the cropland decreased 1.56% annually, with a fall in temporary crops of 3% and a rise of 0.3% in perennial crops. In contrast, pastureland increased 1.0% annually. This situation reflects a structural transformation in Colombian agriculture during that period, when the Colombian government carried out several free-market reforms. It is necessary to mention that such changes began during the 1981–2001 period, when cropland decreased 0.20% and pastureland increased 0.91%; previously, during 1961–1980, cropland increased 1.50% and pastureland, 1.68%.

In addition, during the 1991–2001 period, everything decreased in the Colombian agricultural sector: labor decreased 0.09%, fertilizer, 0.28%; and machinery, 3.82%. In relation to labor, it decreased in most of the periods, but surprisingly it increased during the 1981–2001 period; in contrast, fertilizer, with the above exception (1991–2001), increased during the rest of the periods.

Machinery shows a steady trend toward decreasing, and this fact is an indication of a less favorable situation for investing in agriculture, probably because of the sharp social

Table 10 Annual growth rates of agricultural production factors (%), 1961–2001

Production Factor	Selected Years					
	1961–1970	1971–1980	1981–1990	1991–2001	1961–1980	1981–2001
Cropland (ha)	1.40	2.50	1.00	−1.60	1.50	−0.20
Pastureland (ha)	1.88	1.56	0.84	1.01	1.68	0.91
Labor (thousands)	1.37	−2.22	0.66	−0.31	−0.20	0.72
Fertilizers (tons)	9.56	4.67	8.47	−0.28	6.65	4.54
Machinery (H.P.)	5.00	2.02	1.00	−4.00	4.00	−1.00

and political conflict in rural Colombia. Furthermore, because Colombia does not produce heavy rural machinery and because the importation of some items such as tractors in the past incurred high tariffs, especially in years previous to the 1990s.

Productivity ratios Labor productivity increased at a good pace during the major part of the analysis period, but it began to decrease from 1981–2001 (Table 11). The trend of the components of this ratio (O/L), that is, land productivity (O/A) and land per worker (A/L), shown in Figure 1, indicates that land productivity has exhibited more dynamic behavior than land per worker.

According to theory (Hayami and Ruttan, 1985), that means that biological innovations (improved varieties, pest management, etc.) have been adopted by farmers, and those innovations have been more important than mechanical innovation, as indicated by the land-per-worker ratios. It is a matter of worry that the labor and land

Table 11 Annual growth rates in labor and land productivity (%), 1961–2001

Input	1961–1970	1971–1980	1981–1990	1991–2001	1961–1980	1981–2001
Labor productivity (O/L)	2.01	7.06	2.31	0.07	4.15	1.87
Area/labor (A/L)*	0.43	3.91	0.20	0.97	1.92	0.99
Land productivity (O/A)**	1.57	3.15	2.11	−0.90	2.13	0.88

Note: O/L = (A/L) (O/A).
*Mechanical technology.
**Biological technology.

productivities and the A/L ratio decreased from 1961–1980 to the 1981–2001 period, since this situation is very inconvenient for facing more competitiveness in national and international markets (Figure 5).

Another way to view Colombian technological development is by analyzing the proxy index for factors substituting for land (F/A) and the proxy index for factors substituting for labor (M/A), where fertilizers = F, machinery = M, area = A, and workers = L. As shown in Table 12, the F/A ratio has a more dynamic trend than M/A during the whole period of analysis, even during the 1991–2001 period, which means that agricultural technological development in Colombia has saved relatively more land than labor.

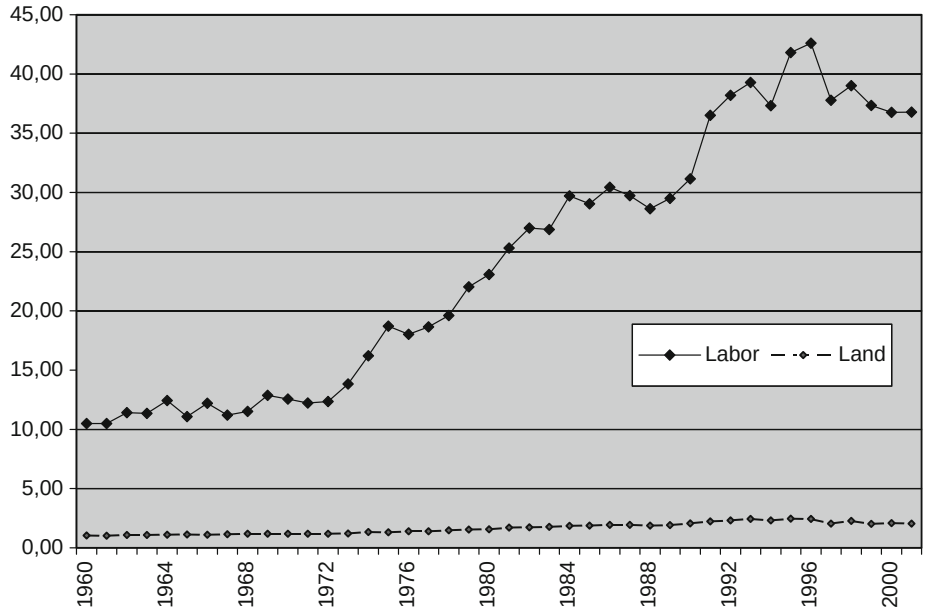

Figure 5 Land and labor productivity in Colombia (Colombian pesos), 1960–2001.

Table 12 Annual growth rates in fertilizer and HP/ha and capital stock/worker (%), 1961–2001

Input	1961–1970	1971–1980	1981–1990	1991–2001	1961–1980	1981–2001
Fertilizer (F.)/ha	8.19	2.18	7.44	1.29	5.88	4.70
HP tractor (M)/ha	3.21	0.00	−2.60	−2.32	2.07	−1.34
Capital stock (K)/worker	−0.68	6.41	−1.56	−0.42	2.76	−0.56

During the 1990s this tendency lost much of its dynamism in Colombian agriculture, as shown in Figure 6. Note that fertilizer is still an important source of productivity in Colombia.

To complete our analysis, the ratio of capital stock (K) per worker (L) was estimated. It is difficult to measure the contribution of work capital assets in the improvement productivity in the Colombian agricultural sector.

Total factor productivity The evolution of the input cost shares for Colombia is presented in Table 13. Note that labor (wage bill) shows a natural and expected decreasing tendency from 1960–1990 but recovers its importance in 2001; on average, for 1961–1980 and 1981–2001, labor maintains high participation as a cost of production.

It is necessary to mention that during the last period, Colombia carried out a decentralization process, transferring important resources to small cities and providing some employment opportunities to the farmer; in some ways this fact helps retain some of the people migrating from the rural sector.

In contrast, intermediate consumption of modern inputs increased participation in factor cost shares, from 1960–1990 and 2001. In spite of the Colombian agriculture crisis, these inputs remained with high participation during 1981–2001 (29%). This trend is probably a consequence of the technological package coming from the Green Revolution and still in wide use in Colombian agriculture.

Land and capital, represented by their rental values, show a steady tendency to decrease over the whole period of analysis. These trends confirm the results from the

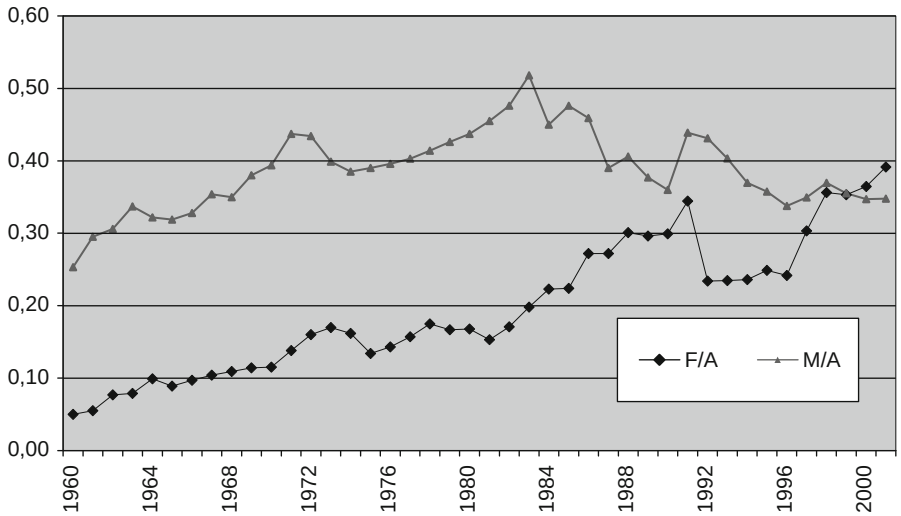

Figure 6 Fertilizer and horsepower by area in Colombia, 1960–2001.

Table 13 Colombian input costs shares (%), 1960–2001

Year	Labor (Wage Bill)	Modern Inputs	Land (Rental Value)	Capital (Rental Value)
1960	46	14	20	20
1970	41	22	18	19
1980	40	24	21	15
1990	34	34	17	15
2001	43	34	11	12
1961–1981	43	20	20	17
1981–2001	41	29	16	14

partial productivity analysis, that is, the loss of importance of the capital as a source of growth in the agricultural sector in Colombia. As mentioned before, capital is defined here as machinery, livestock, and land improvements.

Finally, we obtained TFP indexes (output, inputs, and multifactorial), as shown in Figure 7, based on the information shown in Appendix 2.

The analysis of the TFP evolution by annual rate of growth allows us to perform some kind of source-of-growth analysis. In Table 14 we observe that during the

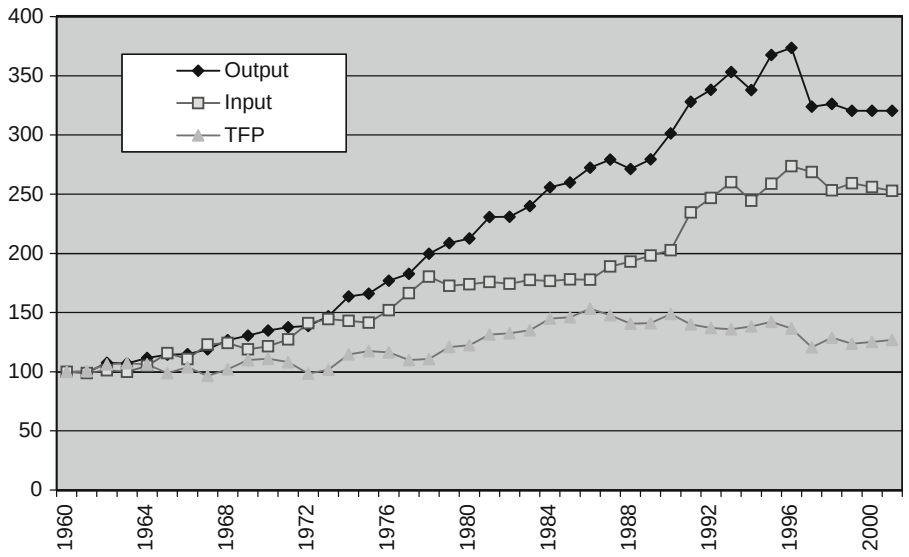

Figure 7 Colombian TFP index for output, input, and multifactorial productivity, 1960–2001.

Table 14 TFP average annual growth rates for Colombia (%), 1961–2001

	1961–1970	1971–1980	1981–1990	1990–2001	1961–1980	1981–2001
Output	3.38	4.84	2.97	−0.23	4.00	1.64
Inputs	2.26	3.45	1.49	0.93	2.95	1.79
Labor	0.51	1.16	−0.06	1.16	0.94	0.80
Modern inputs	1.11	1.10	1.60	−0.14	1.07	1.13
Capital	0.31	0.92	−0.18	−0.24	0.64	−0.24
Land	0.33	0.27	0.13	0.16	0.30	0.10
Productivity	1.12	1.51	1.48	−1.18	1.05	−0.19

1961–1980 and 1981–2001 periods, the contribution of the multifactorial productivity is less than the contribution of inputs to the output annual growth rate. In addition, during the 1990–2001 period, this TFP index decreased at a rate of 1.18% annually; the output growth also decreased (−0.23%). The rate of growth in inputs was positive and rather low at the total.

Observing the four decades, we can characterize each as follows: 1961–1970 as the "take-off" period, when the national agricultural research institute was created and it developed many improved varieties and some other technological products; 1971–1980 as the acceleration period, when the product or research were diffused and adopted by farmers and the Colombian government assigned important financial resources to agricultural research and extension; 1981–1990 as the stagnation period; and 1990–2001 as the decreasing period, related to less support from the government and institutional change concerning agricultural research.

4.1.3 Other LAC TFP studies

The TFP for the Argentinean agricultural sector was recently calculated by Lema and Parellada (2001). The results showed that agricultural TFP growth rates in this country were positive during all of the periods of analysis. The TFP estimated for the entire period of analysis, 1970–1997, was 1.55%. The best performance was found in 1970–1980, with 2.21%; the worst occurred during 1980–1990, when growth was only 0.34%.

Arias and Rodríguez (2002), in their paper on the evolution and performance of the agricultural sector in Costa Rica, estimated the total factor productivity for the 1977–2000 period. The rate of growth for the Costa Rican agricultural sector was strongly positive in the beginning of the period of analysis and relatively modest for the rest of the period. The estimated TFP growth rate for the entire period was 0.45%.

Madrid-Aris (1997) estimated the total factor productivity for the Cuban agricultural sector during the 1963–1988 period. The author estimated a negative rate of growth for the agricultural sector for the period of analysis (−1.5%) and for all the three desegregated periods (1963–1970, 1971–1980, and 1981–1988). The paper also includes TFP indexes for the rest of the Cuban economy.

Avila and Evenson (1995) estimated Tornqvist-Theil TFP indexes for the Brazilian agricultural sector and by subsector (crops and livestock) for the 1970–1985 period based on the agricultural census data. Their study also included TFP indexes by each one of the five Brazilian macro regions (North, Northeast, Southeast, South, and Center-West) and by agroecological zones.

The Avila and Evenson results were higher in the Southeast and Center-West regions (3.1% and 3.8%, respectively), where the Cerrados, the new agriculture frontier in Brazil, is located. The annual rate of growth for the entire Brazilian agricultural sector was estimated at 2.45%, whereas by subsector the higher value was found for crops (3.63%). The annual TFP growth rate at the livestock subsector was 2.12%.

Another Brazilian TFP study was developed by Gasques and Conceição (2001), also based on the agricultural census data and using the Tornqvist-Theil formula. The authors estimated TFP indexes for the entire country and by Brazilian state but only for the agricultural sector as a whole (aggregate). The aggregated annual growth rate estimate was 2.33%. The desegregated TFP results showed that only two of the 27 Brazilian states posted negative productivity growth. The higher annual TFP growth rates were found in states located in the central regions, consistent with the results shown earlier. The poorest performance was verified as the states located in the Amazon region, a non-traditional region for agricultural and livestock production and not directed affected by the recent technological boom of the agricultural sector in the South and Center of Brazil.

Araujo et al. (2002) estimated TFP growth rates of the agricultural sector in the state of São Paulo, one of the more developed Brazilian states. The TFP rates estimated by the authors for the 1960/1999 period showed an average annual growth rate of 1.71%. During the first decade (1960/70) the annual rate of agricultural TFP was very low but for the 1970/99 period the authors found an annual rate greater than 2% per year.

Finally, is important to highlight the results obtained by Gasques et al. (2004). The Tornqvist indexes estimated by these authors for the 1974/2002 period and sub-periods are presented in the Table 15. All the TFP growth rates estimated by Gasques et al. (2004) are very high but consistent with the results presented above.

The overall TFP growth rates of the Brazilian agricultural sector estimated by Avila and Evenson (1995), Gasques and Conceição (2001), Gasques et al.(2004) or those presented early in this section show rates that are relatively high, according to the LAC studies presented earlier. These results are also high compared with TFP index estimates in other world regions or those estimated in developed countries, such as the United States (around 1.5%).

Table 15 Brazilian agricultural TFP growth rates by decade

Period	Output index	Input index	TFP index
1975–2002	3.28	−0.02	3.30
1975–1979	4.37	−0.10	3.62
1980–1989	3.38	0.19	1.52
1990–1999	2.99	−0.17	4.88
2000–2002	5.89	−0.53	6.04

Source: Gasques et al., 2004.

4.2 LAC TFP using FAO databases

Table 16 shows the results of the recent estimates of TFP growth rates for LAC and all its four subregions and countries according to methodology developed by Evenson and Avila (2004). In the aggregate, the LAC performance was very good for both periods (1962–1981 and 1982–2001).

The results by subregion show us that the Caribbean region presents the poorest performance, especially in Cuba and Trinidad and Tobago. The table also includes estimates for the agricultural and livestock sectors, where we found that livestock performs better than the crop sector in the first period. The crop sector presents a better performance in the second period, especially in the Southern Cone (Brazil, Argentina, and Chile) and Andean regions.

During 1980–2001 the majority of the countries in Central America presented a poor performance in productivity growth in agriculture. The Caribbean countries continued with negative or small rates of growth in TFP.

5. SOURCES OF PRODUCTIVITY GROWTH

5.1 Agricultural research

According to Figure 8, public research expenditure in LAC remained almost the same proportion of total world expenditure from 1976 (9.22%) to 1995 (9.00%). In this same period, China and other Asian and Pacific countries increased their participation in the total of agricultural research expenditures (17.21% to 30.89%).

As shown in Table 17, in average, Latin America spent 1.12% of its agricultural GDP in 1996, almost double that spent in 1976. Intensities in 1996 varied, from 0.13% for Guatemala to 1.73% for Brazil. In the LAC region the majority of the countries increased their participation from 1976 to 1996, with the exception of Chile and Guatemala.

Table 16 TFP growth rates for LAC regions (%), 1961–2001

Regions and Countries	Agricultural TFP Growth Rates (%)						
	Crops		Livestock		Aggregate		
	1961–1980	1981–2001	1961–1980	1981–2001	1961–1980	1981–2001	Average
Southern Cone	1.49	3.14	0.72	2.51	1.02	2.81	1.92
Argentina	3.08	3.93	0.90	0.43	1.83	2.35	2.09
Brazil	0.38	3.00	0.71	3.61	0.49	3.22	1.86
Chile	1.08	2.22	0.24	1.87	0.69	2.05	1.37
Paraguay	3.97	−1.01	−0.36	1.29	2.63	−0.30	1.17
Uruguay	1.29	2.02	−0.32	0.53	0.01	0.87	0.44
Andean	1.11	1.71	1.73	1.92	1.41	1.81	1.61
Bolivia	1.73	3.14	2.81	1.39	2.30	2.33	2.31
Colombia	2.01	1.27	0.49	2.24	1.37	1.73	1.55
Ecuador	−0.74	2.24	0.98	2.51	−0.16	2.34	1.09
Peru	−0.83	1.86	1.86	2.14	0.36	1.98	1.17
Venezuela	2.42	0.87	3.41	1.07	3.03	0.99	2.01
Central America	1.65	1.05	2.77	1.53	2.17	1.32	1.74
Costa Rica	2.86	2.09	1.10	0.75	1.74	1.19	1.47
El Salvador	1.22	−0.87	1.99	1.00	1.77	0.32	1.05
Guatemala	3.31	0.53	0.90	−0.28	1.38	−0.08	0.65
Honduras	1.54	−0.39	2.07	1.91	1.91	1.25	1.58
Mexico	1.53	1.43	3.02	1.63	2.26	1.51	1.89
Nicaragua	1.33	−0.70	2.94	1.92	2.25	0.99	1.62
Panama	2.29	−1.33	1.61	1.49	1.93	0.02	0.97
Caribbean	0.74	−2.05	1.20	0.64	0.98	0.29	0.64
Cuba	0.88	−2.88	−0.26	−1.03	0.12	−1.69	−0.78

Continued

Table 16 TFP growth rates for LAC regions (%), 1961–2001—Cont'd

Regions and Countries	Agricultural TFP Growth Rates (%)						
	Crops		Livestock		Aggregate		
	1961–1980	1981–2001	1961–1980	1981–2001	1961–1980	1981–2001	Average
Dominican Rep.	0.99	−1.15	1.88	2.60	1.62	0.89	1.25
Haiti	0.60	−1.04	3.44	1.80	2.73	1.00	1.87
Jamaica	−0.65	1.32	3.28	−0.35	2.07	0.29	1.18
Trinidad and Tobago	−0.88	0.16	3.00	−1.39	1.80	−0.80	0.50
Average rate	*1.45*	*2.26*	*1.39*	*2.13*	*1.36*	*2.24*	1.80

Source: Evenson and Avila (2004).

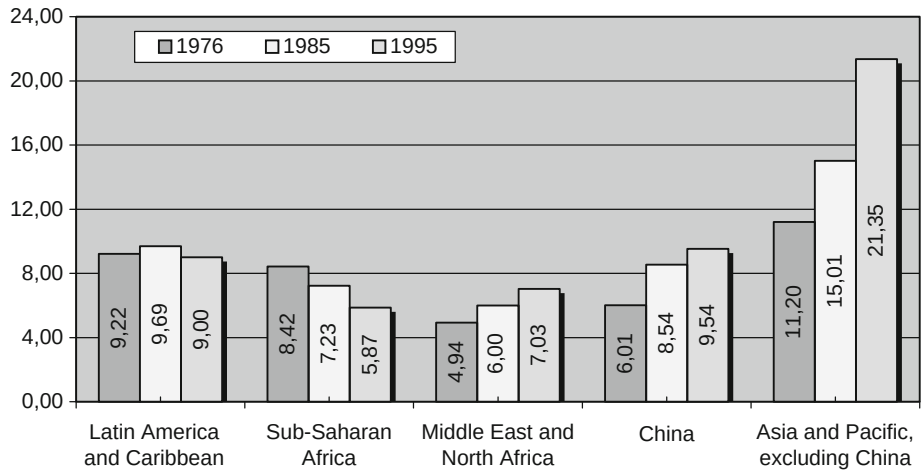

Figure 8 Global public agricultural research expenditures: Regional shares (%), 1976–1995.

The government remains the principal source of resources for agricultural research in the LAC region, with 71% of the total in 1996, even though government spending ranged from 82% in Brazil to 13% in Honduras. Nonprofit organizations represent a small part of the total, but this means a significant share in Colombia and some Central American countries. Higher-education institutions are a very important source of agricultural research in countries such as Argentina (42%), Mexico (45%), and Uruguay (39%). Table 18 shows these ratios for selected LAC countries.

Table 17 LAC public agricultural research expenditures as a share of the agricultural GDP, 1976–1996

LAC Country	1976	1986	1996
Argentina	0.79	0.95	1.12
Brazil	0.75	1.00	1.73
Chile	1.92	1.64	1.43
Colombia	0.25	0.48	0.53
Costa Rica	0.53	0.72	0.56
Guatemala	0.22	0.31	0.13
Honduras	0.17	0.71	0.34
Mexico	0.48	0.61	0.88
Panama	0.64	1.35	1.07
Paraguay	0.06	0.13	0.18
Uruguay	0.52	0.77	1.70
Average	**0.59**	**0.79**	**1.12**

Source: Beintema and Pardey (2001).

Table 18 Composition of the agricultural research expenditures in LAC, 1996

LAC	Government		Nonprofit Organizations	Higher Education
Country	Principal	Other		
Argentina	51	7	—	42
Brazil	59	23	3	15
Chile	49	18	—	33
Colombia	57	10	24	9
Costa Rica	33	4	28	35
Guatemala	57	—	41	2
Honduras	13	—	84	3
Mexico	44	9	2	45
Panama	81	8	—	11

Continued

Table 18 Composition of the agricultural research expenditures in LAC, 1996—Cont'd

LAC Country	Government		Nonprofit Organizations	Higher Education
	Principal	Other		
Paraguay	75	—	0	25
Uruguay	47	14	0	39
Average	**54**	**17**	**4**	**25**

Source: Beintema and Pardey (2001).

5.2 Studies of rates of return

Table 19 shows that in developing countries the median of the estimated rates of return is lower in Africa and Middle East/North Africa than in LAC or Asia. Similarly, the median of the estimates is higher in Europe and North America than in Australia, New Zealand, Japan, and Israel. However, the table also indicates that on average, the developing and developed countries and the CGIAR centers have high and similar rates of return for agricultural research.

Table 19 Median of rates of return for agricultural research by world region, 1996

Geographical Region	Rate of Return (%)
Developed countries	46.0
United States and Canada	46.5
Europe	62.2
Australia and New Zealand	28.7
Japan and Israel	37.4
Developing countries	43.0
Africa	34.3
Asia/Pacific	49.5
Middle East/North Africa	36.0
Latin America	41.0
CGIAR centers	40.0

Source: Alston et al. (2000) and Avila (2002), updated by the authors.

The results presented are a strong indicator that agricultural research is playing an important role in the progress of the agricultural sector in the world and certainly was responsible for a large part of the agricultural productivity growth observed in recent decades.

In LAC more than 130 economic studies were developed to evaluate the impact of agricultural research. As shown on Table 20, Brazil is the leader in the development of this kind of study and was responsible for almost 50% of them. Some other countries also have performed a significant number of studies and calculations on this matter, as in the case of Ecuador, Colombia, Argentina, Peru, and Mexico.

By subregion, the Southern Cone presents the major number of calculations, followed by the Andean region; the Caribbean has no studies about impact evaluation. Appendix 3 presents an updated list of the main studies developed in the region.

Particularly in the case of Brazil, it is important to note that the majority of these studies (75%) were developed or directly supported by Embrapa, the Brazilian Corporation for Agricultural Research. The continuous development of impact assessment studies at Embrapa, by their own researchers or by invited experts, are an institutional priority (Avila, 2002). If we focus the LAC by sector, we note the absence of estimations concerning fishery, forestry, and soil and water, since there is now a great deal of interest in investment of this kind and the necessity to evaluate its social and economic value.

The majority of the studies (98) are related to crops; 20% are aggregated and only five are from livestock. This is also a surprisingly low number, which does not correspond with the importance of this activity within the region. When we analyze the 130 LAC studies by commodity, soybeans and rice show the major number of estimations in Brazil, and wheat, maize, potato, and rice are the dominants in the rest of LAC.

Table 20 Regional frequency of agricultural research impact studies

Southern Cone		Andean		Central America	
Brazil	61	Colombia	13	Mexico	7
Argentina	12	Ecuador	14	Panama	1
Chile	3	Peru	9	Honduras	2
Uruguay	1	Bolivia	0	Others	0
Paraguay	0	Venezuela	0	Caribbean	0
—	—	Peru/Colombia	1	—	
PROCISUR	3	PROCIANDINO	1	—	
Subtotal	**80**	**Subtotal**	**38**	**Subtotal**	**10**
Latin America			**2**	**Total LAC**	**130**

The results show us that in all countries the returns were superior to other economic activities. This means that agricultural development depends on investments in science and technology generation.

5.3 Rural extension services

In the last three decades, the rural extension services in Latin America have been undergoing important transformations. The public extension workers, very important during the 1960s and 1970s, are gradually being replaced by the private sector. The majority of commercial farmers, especially in the Southern Cone, are now assisted by private extension workers paid by their own rural extension service. Actually, the public extension workers are more concentrated in the technical and social assistance of small farmers. Table 21 presents a small picture of the situation of the rural extension service in Latin America during the 1980s, according to FAO databases.

Table 21 Public extension workers in Latin America by subregion and country, 1985

Country	Number of Public Extension Workers	Country	Number of Public Extension Workers
Argentina	400	Costa Rica	233
Brazil	1407	El Salvador	90
Chile	450	Guatemala	363
Paraguay	136	Honduras	280
Uruguay	20	Mexico	680
Southern Cone	2413	Nicaragua	85
Bolivia	80	Panama	1124
Colombia	1832	Central America	2855
Ecuador	150	Dominican Rep	70
Peru	650	Haiti	360
Venezuela	1271	Jamaica	475
Andean	3983	Caribbean	4884

Source: FAO (1985).

Although the numbers of extension workers have changed in the past two decades, this service (public and private) continues to be an important source of agricultural productivity growth.

The difficulties experienced by extension work in LAC are present in all countries. The general feeling is that extension should be serviced by private sector and the public extension should be strictly oriented to small farmers. The future agricultural policy should consider the access of large, medium-sized, and small farmers to extension services (whether public or private); otherwise many new technologies will not be diffused among the potential producers.

5.4 Schooling

Schooling is one the most important sources of growth in agricultural productivity. Figure 9 presents the evolution of the number of years of education for adult males from 1970–2000, according to the World Bank. This variable, from the Barro-Lee database of the World Bank, is not specific to agricultural workers.

It is probably the case that the average schooling of agricultural workers is lower than the average schooling for all workers. But for our purposes, it is the growth rate in schooling that is important. Again, in this case the Southern Cone is the subregion of Latin America with better indexes, followed by the Andean region.

5.5 Nutrition

Another source of productivity growth is the Dietary Energy Sufficiency (DES). Figure 10 presents the DES index published by the FAO for the 1970–2000 period. This index is based on consumption data and effectively is an average calories per capita measure. Both measures are reported by developing country regions to show the diversity in changes in these indexes.

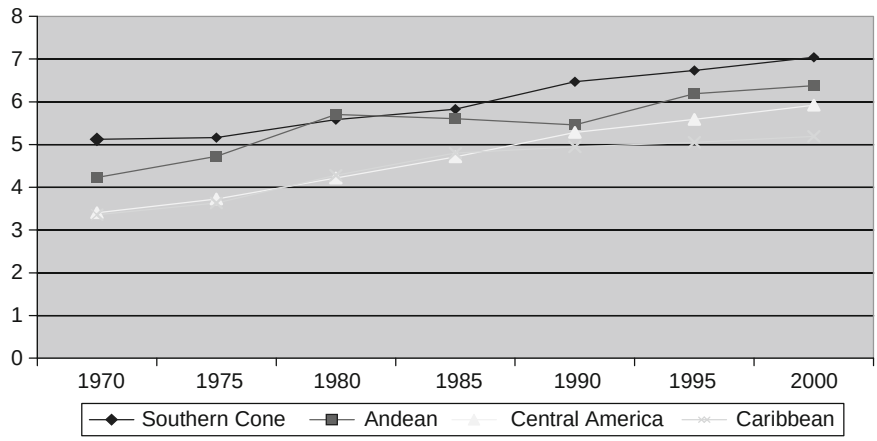

Figure 9 Schooling in Latin America (years of schooling in adult males), 1970–2000.

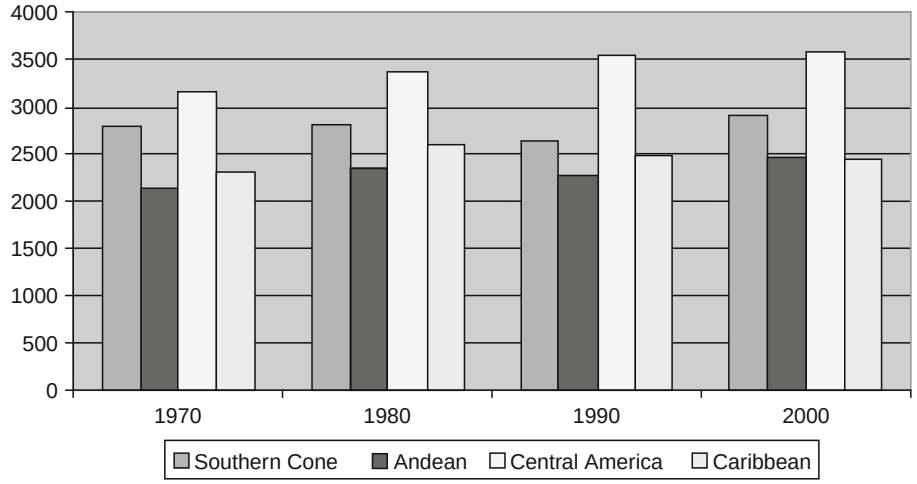

Figure 10 Dietary energy sufficiency index, 1970–2000.

The data show that in Latin America, the countries located in the Central America subregion are those with better dietary energy indexes. This index is also growing faster there than in other LAC subregions.

6. ANALYSIS OF THE DETERMINANTS OF TFP GROWTH IN LAC

In this section we analyze the relationship between the sources of productivity growth discussed in the previous section and the estimated TFP of the agricultural sector of Latin America and the Caribbean. The analysis of the determinants of the agricultural TFP growth included 20 LAC countries and two periods (1961–1980 and 1981–2001). In this analysis we used the same TFP decomposition framework adopted by Avila and Evenson (2004) to evaluate the determinants of agricultural TFP growth in the developing countries. This model, adapted for the LAC case, is a three-equation model as described here:

AdopMV: Instruments
GrDES: Instruments
Aggregate TFP: AdopMV, GrDES, GrASch, Lac1, Lac2, Lac3

where

TFP_{ct} is the TFP index value for each LAC country c for period t.
$AdopMV_{ct}$ is the adoption rate of modern varieties weighted by crop area.
$GrASch_c$ is the growth rate of average years of schooling of adult males between periods.

$GrDES_c$ is the growth rate on the Dietary Energy Sufficiency (DES) index (published by the FAO) between periods.
Lac1, Lac2, and Lac3 are dummy variables for each LAC subregion (Southern Cone, Andean, and Central America, with the Caribbean region left out).

The instruments for AdopMV and GrDES include the exogenous variables in the aggregate TFP equation, Lac1, Lac2, Lac3, and GrASch, plus innovation classes dummy variables IrrigLand, Extwork, and Rurpopden. These other variables mean the following:

RurpopDen is the rural population density by country for period *t*.
Extwork is the number of extension workers in each country for period *t*.
In Class2 to InClass6 are dummies for innovation class variables (explanation below).

These innovation classes, according to Avila and Evenson (2004), measure the research capacity of each country. They were constructed using the ratio of agricultural researchers by cultivated area and the percentage of GDP applied in R&D. The distribution of Latin American countries by innovation classes is as follows:

Innovation class D24: Nicaragua, Ecuador, and Dominican Republic
Innovation class D32: Honduras
Innovation class D33: Haiti and Paraguay
Innovation class D34: Uruguay
Innovation class D35: Guatemala, Panama, Peru, and Venezuela
Innovation class D44: Bolivia, Colombia, and Jamaica
Innovation class D45: Argentina and Mexico
Innovation class D55: Costa Rica
Innovation class D56: Chile, El Salvador, and Brazil

The numbers represent classes during each period of analysis (1961–1980 and 1981–2001). For estimation purposes, we grouped the countries in five classes (2 through 6) and according to the classification by period. This aggregation was based on the innovation index for the first period, except in case of the Group 3, which was split into two subgroups, −32 + 33 and 34 + 35. It is important to note that a low number, D24, for example, means a low grade of innovation, whereas D56 represents the highest grade of science and technology development. That leaves four innovation classes (InClass2, InClass3, InClass4, and InClass5) in the econometric model and one class left out (InClass6) for estimation purposes.

Two of the three variables (AdMV and GrDES) are treated as endogenous in the TFP model. The method used to deal with this fact is to use instrumental variables.

The instruments for AdopMV and GrDES include the exogenous variables in the aggregate TFP equation, Lac1, Lac2, and Lac3, and GrASch, plus the innovation class dummies (2 through 5), extension workers, and rural population density.

Table 22 reports the estimates for both the first-stage instrumented variables, AdoptMV and GrDES, and the second-stage aggregate TFP equations. Adoption of modern varieties, the growth in schooling, and improved dietary nutrition had positive and significant effects on agricultural TFP growth in LAC countries.

These results confirm those obtained by Avila and Evenson (2004) for all the developing countries in which the adoption of Green Revolution modern varieties, increases in schooling of the labor force, and increases in dietary energy were identified as sources of TFP growth.

7. INCOME IMPROVEMENT: POVERTY REDUCTION STUDIES

The information given in this section is based on studies and publications from the Economic Commission for Latin America and the Caribbean (ECLAC), which has the basic function of monitoring the economic and social situation of the LAC countries and analyzing the public policies carried out to reach some important development goals.

The information presented here is heavily based on ECLAC publications such as *A Decade of Social Development in Latin America, 1990–1999* (2000), *Social Panorama of Latin America, 2002–2003* (2004), and *Meeting the Millennium Poverty Reduction Targets in Latin America and the Caribbean* (2002). This information has to do with the magnitude and profile of poverty, factors related to poverty reduction, income distribution, and the millennium poverty reduction targets.

7.1 Poverty magnitude

According to Table 23, although the percentage of poor people out of the total population decreased in most LAC countries in the 1990s, the number of poor rose from 200 million to 211 million. In addition, the poor population represented 40.5% of the total in 1980, 48.3% in 1990, and 43.5% in 1999.

In terms of indigent people (extreme poverty), the figures were 18.6% for 1980, 22.5% for 1990, and 18.5% for 1999. So, comparing 1980 with 1999, the region made no progress in this matter in two decades (ECLAC, 2000). For 2002, the percentage of poor were estimated to be 44% and those in indigence or extreme poverty, 19.4% (ECLAC, 2004).

Table 24 presents the situation of poverty and indigence by country (18). According to the table, poverty rates fell in 11 countries in the region, representing the bulk of the population: Brazil, Chile, and Panama hold the best performance, followed by Costa Rica, Guatemala, and Uruguay. In contrast, Bolivia, Ecuador, Paraguay, and Venezuela failed to make progress reducing poverty in the last decade. Colombia made very little progress. In the case of indigence, the picture is almost identical. In addition, it is worth noting that Uruguay shows the smallest rates of poverty and indigence in all the region.

Table 22 Determinants of the TFP growth in Latin America and the Caribbean

	First-Stage Instrumented Variables		Second-Stage Estimates
	Adopt MV	Dietary Nutrition/ Share Labor	Aggregate TFP
Growth rate Schooling × Labor Force	−5.81 (−2.51)	4.29 (1.57)	0.3994 (2.27)
Lac 1: Southern Cone	46.08 (3.11)	−5.73 (−0.33)	−0.61 (−0.46)
Lac 2: Andean	19.28 (1.25)	2.98 (0.16)	−0.147 (−0.12)
Lac 3: Central America	20.74 (1.37)	−11.25 (−0.63)	0.280 (0.27)
Innovation class2	−29.13 (−1.77)	11.97 (0.61)	
Innovation class3	−32.50 (−2.66)	7.57 (0.52)	
Innovation class4	−29.67 (−3.33)	19.99 (1.90)	
Innovation class5	−15.36 (−2.82)	2.77 (0.43)	
Extension workers	−0.003 (−5.03)	0.004 (4.92)	
Rural population density	−2.77 (−1.58)	6.05 (2.93)	
Adoption rate, modern varieties			0.0662 (2.88)
Dietary Nutrition x Labor Force			0.0377 (1.94)
# obs	40	40	40
R-*squared*	0.77	0.57	0.58
Prob > F	0.0000	0.0022	0.0023

Table 23 Latin America: Poor and indigent households and individuals, 1980–1999 (M households and individuals and %)*

Year	Poor**						Indigent***					
	Total		Urban		Rural		Total		Urban		Rural	
	M	%	M	%	M	%	M	%	M	%	M	%
	Households											
1980	24.2	34.7	11.8	25.3	12.4	53.9	10.4	15.0	4.1	8.8	6.3	27.5
1990	39.1	41.0	24.7	35.0	14.4	58.2	16.9	17.7	8.5	12.0	8.4	34.1
1999	41.3	35.3	27.1	29.8	14.2	54.3	16.3	13.9	8.3	9.1	8.0	30.7
	Individuals											
1980	135.9	40.5	62.9	29.8	73.0	59.9	62.4	18.6	22.5	10.6	39.9	32.7
1990	200.2	48.3	121.7	41.4	78.5	65.4	93.4	22.5	45.0	15.3	48.4	40.4
1999	211.4	43.8	134.2	37.1	77.2	63.7	89.4	18.5	43.0	11.9	48.4	38.3

*Estimates corresponding to 19 countries of the region.
**Households and population living in poverty. Includes indigent households (population).
***Indigent households and population.
Source: ECLAC, on the basis of special tabulations of data from household surveys conducted in the respective countries.

Table 24 Latin America: Poverty and indigence indicators (%), 1990–1999

Country	Year	Households and Population Below the Poverty Line*		Households and Population Below the Indigence Line	
		Households	Population	Households	Population
Argentina**	1990	16.2	21.2	16.2	21.2
	1999	13.1	19.7	13.1	19.7
Bolivia	1989***	49.4	53.1	49.4	53.1
	1999	54.7	60.6	54.7	60.6
Brazil	1990	41.4	48.0	41.4	48.0
	1999	29.9	37.5	29.9	37.5
Chile	1990	33.3	38.6	33.3	38.6
	2000	16.6	20.6	16.6	20.6

Continued

Table 24 Latin America: Poverty and indigence indicators (%), 1990–1999—Cont'd

Country	Year	Households and Population Below the Poverty Line*		Households and Population Below the Indigence Line	
		Households	Population	Households	Population
Colombia	1991	50.5	56.1	50.5	56.1
	1999	48.7	54.9	48.7	54.9
Costa Rica	1990	23.7	26.2	23.7	26.2
	1999	18.2	20.3	18.2	20.3
Ecuador****	1990	55.8	62.1	55.8	62.1
	1999	58.0	63.6	58.0	63.6
El Salvador	1999	43.5	49.8	43.5	49.8
Guatemala	1989	63.0	69.1	63.0	69.1
	1998	53.5	60.5	53.5	60.5
Honduras	1990	75.2	80.5	75.2	80.5
	1999	74.3	79.7	74.3	79.7
México	1989	39.0	47.8	39.0	47.8
	2000	33.3	41.1	33.3	41.1
Nicaragua	1993	68.1	73.6	68.1	73.6
	1998	65.1	69.9	65.1	69.9
Panamá	1991	36.3	42.8	36.3	42.8
	1999	24.2	30.2	24.2	30.2
Paraguay	1990*****	36.8	42.2	36.8	42.2
	1999	51.7	60.6	51.7	60.6
Peru	1999	42.3	48.6	42.3	48.6
Dominican Republic	1998	25.7	30.2	25.7	30.2
Uruguay****	1990	11.8	17.8	11.8	17.8
	1999	5.6	9.4	5.6	9.4
Venezuela	1990	34.2	40.0	34.2	40.0
	1999	44.0	49.4	44.0	49.4

Continued

Table 24 Latin America: Poverty and indigence indicators (%), 1990–1999—Cont'd

Country	Year	Households and Population Below the Poverty Line*		Households and Population Below the Indigence Line	
		Households	Population	Households	Population
Latin America (19 countries)	1990	41.0	48.3	41.0	48.3
	1999	35.3	43.8	35.3	43.8

*Includes households (individuals) living in indigence or extreme poverty.
**Greater Buenos Aires.
***Eight departmental capitals plus the city of El Alto.
****Urban areas.
*****Asunción Metropolitan.
Source: ECLAC, on the basis of special tabulations of data from household surveys conducted in the respective countries. For a definition of each indicator, see ECLAC (2004).

Concerning the spatial distribution of poverty, the relative importance of urban poverty continued to increase during the decade; by 1999, 134 million of 211 million poor people lived in urban areas and 77 million in rural areas. One of the most important factors explaining this situation has to do with migration from rural areas to the cities, since the urban economy faces the challenge of absorbing a larger proportion of the working-age population and, consequently, the increased demand for social services, not always with success (ECLAC, 2000).

However, the incidence of poverty is higher in rural areas than in cities, since almost 64% of people are poor and rural compared to 37% in cities. In addition, poverty is more extreme in rural areas, since most of the people there are indigent (46 million of 89 million). In addition, in Bolivia, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Paraguay, and Peru, poverty is still a rural situation, whereas in Colombia, Mèxico, and Dominican Republic, almost 45% of the poor reside in rural areas (Table 25).

7.2 Factors related to poverty

Several studies carried by ECLAC have stablished that poverty levels are affected by economic, demographic, and social factors. The economic factors include economic growth, public transfers, and relative prices. Demographic aand social factors include the size, composition, and geographical location of households as well as the level of education of household members and the labor market (ECLAC, 2000; ECLAC, 2002). Some findings concerning these topics are as follows:

Table 25 Latin America: Magnitude and relative share of rural poverty (%), 1999

Rural Households Below the Poverty Line	Poor Rural Households in Relation to Total Poor Households		
	Less Than 35%	Between 35% and 49%	50% or More
Over 65%			Guatemala Honduras Nicaragua
Between 51% and 65%		Colombia Ecuador México	Bolivia El Salvador Paraguay Peru
Between 31% and 50%	Brazil Panama Venezuela	Dominic Republic	
Up to 30%	Argentina Chile Uruguay		Costa Rica

Source: Prepared on the basis of ECLAC, Social Panorama of Latin America, 1998 (LC/G.2050-P), Santiago, Chile, May 1999. United Nations publication, Sales No. E.99II.G.4, Table 16 of the statistical.

Throughout the decade the ups and downs in per capita income were closely correlated to decreases or increases in poverty, especially in extreme cases—for example, Chile and Venezuela. But similar growth rates have different effects on poverty levels. In Chile, for example, per capita GDP increased 55% from 1990 to 1999; at the same time, poverty fell 50%. Meanwhile, in Uruguay, a much smaller increase in per capita GDP (28%) correlated with a larger decrease in poverty (53%). In Bolivia and Panama, per capita GDP grew at similar rates over the period (16% and 20%), but the decline of urban poverty in both countries was very different: 14% and 25%, respectively (Table 26).

The growth of labor productivity was uneven across various sectors and firms; growth in labor productivity was typical of big companies linked with the international market, although these firms generated few new jobs. In contrast, low-productivity employment, mostly in the informal sector, expanded in nearly all the countries.

On the other hand, public transfers were very important in reducing the incidence of poverty. In Argentina, Costa Rica, Panama, and Uruguay, such transfers represented

Table 26 Latin America (14 countries): Per capita GDP and percentage of the population living in poverty and indigence, 1990–1999

Country	Year	Per Capita GDP (1995 Dollars)	Percentage of the Population		Variation Over the Period (Annual Average)		
			Poor	Indigent	GDP*	Coefficient of	
						Poverty (P)	Indigence (I)
Argentina*	1990	5.545	21.2	5.2			
	1999	7435	19.7	4.8	3.3	−0.8	−0.9
Brazil	1990	3859	48.0	23.4			
	1999	4.204	37.5	12.9	1.0	−2.7	−6.4
Chile	1990	3.425	38.6	12.9			
	2000	5.309	20.6	5.7	4.5	−6.1	−7.8
Colombia	1991	2.158	56.1	26.1			
	1999	2.271	54.9	26.8	0.6	−0.3	0.3
Costa Rica	1990	2.994	26.2	9.8			
	1999	3.693	20.4	7.8	2.4	−2.7	−2.5
Ecuador **	1990	1.472	62.1	26.2			
	1999	1.404	63.5	31.3	−0.5	0.2	2.0
El Salvador	1995	1.675	54.2	21.7			
	1999	1.750	49.8	21.9	1.1	−2.1	0.2
Guatemala	1989	1.347	69.1	41.8			
	1998	1.534	60.5	4.1	1.5	−1.5	−2.2
Honduras	1990	686	80.5	60.6			
	1999	694	79.7	56.8	0.1	−0.1	−0.7
Mexico	1989	3.925	47.8	18.8			
	1998	4.489	46.9	18.5	1.5	−0.2	−0.2
Nicaragua	1993	416	73.6	48.4			
	1998	453	69.9	44.6	1.7	−1.0	−1.6
Panama	1991	2.700	42.8	19.2			
	1999	3.264	30.2	10.7	2.4	−4.3	−7.0
Uruguay**	1990	4.707	17.8	3.4			
	1999	5.982	9.4	1.8	2.7	−6.8	−6.8

Continued

Table 26 Latin America (14 countries): Per capita GDP and percentage of the population living in poverty and indigence, 1990–1999—Cont'd

Country	Year	Per Capita GDP (1995 Dollars)	Percentage of the Population		Variation Over the Period (Annual Average)		
			Poor	Indigent	GDP*	Coefficient of	
						Poverty (P)	Indigence (I)
Venezuela	1990	3.030	40.0	14.6			
	1999	30.37	49.4	21.7	0.0	2.4	4.5
Latin America	1990	3.349	48.3	22.5			
	1999	3804	43.8	18.5	1.4	−1.1	−2.2

*Greater Buenos Aires.
**Total for urban areas.
Source: ECLAC, on the basis of official figures and special tabulations of data from household surveys conducted in the respective countries.

more than 20% of total urban household income and about 10% in Brazil, Chile, Colombia, Ecuador, Mexico, and Venezuela.

7.3 Income distribution

The highly uneven income distribution that has been typical of LAC remained the same or worsened in most of the countries in the 1990s. According to Table 27, the major share of the population (70% and more) in each country were below the average per capita income; also, the high degree of income concentration in Latin America can be inferred from the Gini coefficient.

According to this coefficient, Brazil presents the highest concentration with a Gini index of almost 0.64, followed by Bolivia, Colombia, Nicaragua, Guatemala, and Honduras. By contrast, Uruguay presents the lowest income concentration. Additionally, 11 out of 17 countries showed an increment in income concentration from 1990 to 1999; the rest of the countries made very little progress in this area during the same period (ECLAC, 2000).

Table 28 illustrates another feature of income distribution in Latin America, that is, income distribution is not clearly related to the countries' level of development. For each category of per capita income (high, intermediate, and low) there is high, intermediate, and low income concentration. For example, Argentina and Uruguay, which both have high income levels in regional terms, have very different income distribution structures.

Table 27 Latin America: Indicators of income concentration by country,* 1990–1999

Country	People (%) with Per Capita Incomes Below:			Gini
	Year	Average	50% of Average	Coefficient*
Argentina	1990	70.6	39.1	0.501
	1999	72.5	44.2	0.542
Bolivia	1989★	71.9	44.1	0.538
	1999	70.4	45.5	0.586
Brazil	1990	75.2	53.9	0.627
	1999	77.1	54.8	0.640
Chile	1990	74.6	46.5	0.554
	2000	75.0	48.4	0.559
Colombia	1994	73.6	48.9	0.601
	1999	74.5	46.6	0.572
Costa Rica	1990	65.0	31.6	0.438
	1999	67.6	36.1	0.473
Ecuador★	1990	69.6	33.8	0.461
	1999	72.1	42.0	0.521
El Salvador	1995	69.7	38.4	0.507
	1999	68.5	40.6	0.518
Guatemala	1989	74.9	47.9	0.582
	1998	75.0	49.5	0.582
Honduras	1990	75.1	52.3	0.615
	1999	71.8	46.4	0.564
Mexico	1989	74.2	43.5	0.536
	1998	72.8	43.1	0.539
Nicaragua	1993	71.5	45.9	0.582
	1998	73.1	45.9	0.584
Panama	1991	71.3	46.4	0.560
	1999	72.1	46.4	0.557
Paraguay	1990	69.2	33.4	0.447
	1999	72.3	46.3	0.565
Dominican Republic	1997	71.4	39.8	0.517

Continued

Table 27 Latin America: Indicators of income concentration by country,* 1990–1999—Cont'd

Country	People (%) with Per Capita Incomes Below:		Gini
	Year	Average	50% of Average	Coefficient*
Uruguay*	1990	73.2	36.8	0.492
	1999	67.1	32.2	0.440
Venezuela	1990	68.0	35.5	0.471
	1999	69.4	38.6	0.498

*Low (under 0.48), intermediate (between 0.48 and 0.54), and high (over 0.54) Gini coefficient.

Table 28 Latin America (17 countries): Per capita income and degree of income concentration in urban areas by country, 1999

Per Capita Income	Country	Income Concentration*
High (More than US$4,000)	Argentina	High
	Uruguay	Low
	Chile	High
	Mexico	Intermediate
	Brazil	High
Intermediate (Between US$2,000 and US $4,000)	Costa Rica	Low
	Panama	Intermediate
	Venezuela	Low
	Dominican Republic	Intermediate
	Colombia	High
Low (Less than US$2,000)	El Salvador	Low
	Paraguay	Intermediate
	Guatemala	High
	Ecuador	Intermediate
	Bolivia	Intermediate
	Honduras	High
	Nicaragua	High

Source: ECLAC, based on special tabulations from household surveys in the countries concerned.

7.4 Millenium poverty reduction target

The report *Meeting the Millennium Poverty Reduction Target in Latin America and the Caribbean* (ECLAC, IPEA, and PNUD, 2002) looks at the conditions under which 18 LAC countries would be able to meet the extreme poverty reduction target established by the Millennium Declaration as one of the United Nations Millennium Development Targets.[1] The question that the report seeks to answer is wheather or not each country will succeed in decreasing its 1999 extreme poverty rate by 2015.

For each country, two scenarios were considered: the "historical" one, which extrapolates the countries' growth and inequality dynamics of the 1990s into the future, and the "alternative" one (in comparisson with a "regional ideal"). As expected, the report's findings give reasons for both concern and moderate optimism.

According to the "historical" scenario, if the countries in the sample continue to perform as they did in the 1990s, only seven of them will reach the extreme poverty reduction target; these countries are Argentina, Chile, Colombia, Dominican Republic, Honduras, Panama, and Uruguay. Another six countries would continue to reduce poverty but at a very slow pace: Brazil, Costa Rica, El Salvador, Guatemala, Mexico, and Nicaragua. The rest of the countries—Bolivia, Ecuador, Paraguay, Peru, and Venezuela—would see higher levels of extreme poverty because of increases in inequalities, per capita income, or both.

Concerning the "alternative" scenario and with respect to the international poverty line (which corresponds to a $1-a-day line), it was found that 16 countries could meet the target by combining average annual growth rates of per capita GDP of 3% with cumulative reductions in inequality of 4% or less. The exceptions are Bolivia and El Salvador. The findings appear to indicate that even very small reductions in inequality can have very large positive impacts in terms of poverty reduction, and this effect is more important than the reduction in poverty due to economic growth.

8. CONCLUSION

The partial agricultural productivity indexes and the TFP growth rates analyzed in this chapter show that the Latin American and Caribbean region presents a very diverse situation. In general, the Southern Cone and the Andean regions present more positive indicators. In contrast, the Caribbean region presented the worst productivity indicators.

In general, the countries' TFP results discussed in this chapter indicate a better performance for the LAC countries in the last two decades. This results are compatible with other indicators and sources of productivity growth analyzed in the chapter.

The information concerning the R&D intensities suggests that the results are positive for the region. The share of research expenditure and agricultural GDP is increasing in the majority of the countries, the government continues to present strong sources of funding for agricultural research, and the rates-of-return estimates in the region are comparable to those calculated in developed countries and CGIAR centers.

Brazil is the leader in the development of impact studies, followed by Ecuador, Colombia, Argentina, Peru, and Mexico. By LAC subregion, the Southern Cone presents the major number of calculations, followed by the Andean region; the Caribbean has no studies covering impact evaluation of agricultural research programs.

Schooling and nutrition are three other important sources of productivity growth. In general, the data show good performance by the Latin American countries in these regards. The Southern Cone is again the leader for schooling, but Central American countries present the best indexes for dietary energy sufficiency (DES).

The TFP decomposition exercise confirmed results obtained by other authors in this same kind of study and cited in the economic literature. The adoption of Green Revolution modern varieties, increases in schooling of the labor force, and increases in dietary energy were very important sources of agricultural TFP growth in the Latin American and the Caribbean countries during the last four decades.

End Notes

1. The United Nations Millennium Declaration stipulates that the target is to halve the proportion of extreme poverty that existed in 1990; 1999 was chosen as the reference point because of data availability.

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APPENDIX 1

Table A.1 LAC country population, 1980–2000

Country	Population (Thousands)		Growth Rate (%)
	1980	2000	
Argentina	28.094	37.032	31.82
Bolivia	5.355	8.329	55.53
Brazil	121.672	170.693	40.29
Colombia	28.447	42.321	48.77
Costa Rica	2.284	4.023	76.10
Cuba	9.710	11.199	15.35
Chile	11.147	15.211	36.46
Ecuador	7.861	12.646	58.84
El Salvador	4.586	6.397	36.85
Guatemala	6.920	11.385	66.94
Haiti	5.454	8.357	53.23
Honduras	3.569	6.483	81.73
Jamaica	2.133	2.576	21.10
Mexico	67.570	98.881	46.34
Nicaragua	2.921	5.071	73.71
Panama	1.950	2.856	46.47
Paraguay	3.114	5.496	76.52
Peru	17.324	25.939	48.13
Dominican Republic	5.697	8.396	49.12
Trinidad y Tobago	1.082	1.294	20.06
Uruguay	2.814	3.337	14,54
Venezuela	15.091	24.170	60.16

Source: *Economic Commission for Latin America and the Caribbean 2002 Yearbook*, Santiago de Chile (2003; www.eclac.org).

APPENDIX 2

Table A.2 Colombian agricultural TFP: Input, output, and multifactorial indexes, 1960–2001

Year	Input	Output	Productivity
1960	100	100	100
1961	98.92	99.40	100.49
1962	101.16	107.51	106.27
1963	99.93	107.12	107.19
1964	104.99	111.57	106.27
1965	115.61	114.33	98.90
1966	110.69	114.83	103.75
1967	122.99	118.83	96.61
1968	124.17	126.68	102.02
1969	118.92	130.56	109.79
1970	121.46	134.74	110.93
1971	127.17	137.50	108.13
1972	141.07	138.72	98.33
1973	144.36	146.72	101.64
1974	142.91	163.63	114.50
1975	141.51	165.93	117.25
1976	152.03	176.93	116.38
1977	166.28	182.61	109.82
1978	180.43	199.64	110.65
1979	172.66	208.72	120.88
1980	173.94	212.61	122.23
1981	175.72	230.67	131.27
1982	174.27	230.87	132.48
1983	177.63	239.90	135.06
1984	176.69	255.87	144.81

Continued

Table A.2 Colombian agricultural TFP: Input, output, and multifactorial indexes, 1960–2001—Cont'd

Year	Input	Output	Productivity
1985	177.99	259.77	145.94
1986	177.65	272.34	153.30
1987	189.02	279.11	147.66
1988	193.00	271.18	140.51
1989	198.13	279.36	141.00
1990	202.75	301.44	148.68
1991	234.42	328.04	139.94
1992	246.82	338.14	136.99
1993	260.15	353.18	135.76
1994	244.36	337.94	138.30
1995	258.76	367.48	142.01
1996	273.59	373.49	136.51
1997	268.74	323.97	120.55
1998	253.22	326.27	128.85
1999	259.23	320.43	123.61
2000	256.06	320.43	125.14
2001	252.67	320.43	126.82

APPENDIX 3

Table A.3 The Brazilian experience on agricultural research impact evaluation (IRR)

Authors and Year	Location (Country, State, Center, etc.)	Commodity/Level	IRR (*)
1. Ayer and Schuh (1972)	State of São Paulo	Cotton	77
2. Monteiro (1975)	Brazil	Cocoa	16–18
3. Fonseca (1976)	Brazil	Coffee	23–26
4. Moricochi (1980)	State of São Paulo	Citrus	28–78
5. Avila (1981)	State of Rio Grande do Sul	Irrigated rice	87–119
6. Cruz, Palma, and Avila (1982)	Embrapa research	Aggregate	22–43
7. Ribeiro (1982)	State of Minas Gerais	Rice Cotton Soybeans	69 48 36
8. Cruz and Avila (1983)	World Bank Project: Embrapa research	Aggregate	20–38
9. Avila, Borges, Irias, and Quirino (1984)	Embrapa Human Capital	Training program	22–30
10. Roessing (1984)	Soybeans Research Center, Embrapa	Soybeans	45–62
11. Ambrosi and Cruz (1984)	Wheat Research Center, Embrapa	1974–1982	59–74
12. Avila, Irias, and Veloso (1985)	IDB Agricultural Research Project I: Embrapa research South research system	 Aggregate Aggregate	 27 38
13. Monteiro (1985)	Minas Gerais and Espirito Santo states	Cocoa	61–79
14. Barbosa, Cruz, and Avila (1988)	Embrapa research	Aggregate	34–41
15. Barbosa, Avila, and Motta (1988)	World Bank Project II: Embrapa research	Aggregate	43
16. Kitamura et al. (1989)	Embrapa research: North region	Aggregate	24

Continued

Table A.3 The Brazilian experience on agricultural research impact evaluation (IRR)—Cont'd

Authors and Year	Location (Country, State, Center, etc.)	Commodity/Level	IRR (*)
17. Santos et al. (1989)	Embrapa research: Northeast region	Aggregate	25
18. Teixeira et al. (1989)	Embrapa research: Center/West region	Aggregate	43
19. Lanzer et al. (1989)	Embrapa research: South region	Aggregate	45
20. Santos and Barros (1989)	Cotton Research Center, Embrapa	Aggregate	24–37
21. Gonçalves, Souza, and Rezende (1989)	São Paulo state	Rice	85–95
22. Kahn and Souza (1991)	Cassava and Fruit Research Center, Embrapa	Cassava and cow-pea crop system	29–46
23. Barbosa and Cruz (1993)	IDB Project II: Embrapa research	Aggregate	43
24. Dossa and Contini (1994)	Soybeans Research Center: a reevaluation	Soybeans	65
25. Avila and Evenson (1995)	a1) Embrapa national programs	Aggregate (1)	56
	b1) Embrapa regional centers		46
	c1) State research		19
	a2) Embrapa national programs	Livestock (2)	90
	b2) Embrapa regional centers		25
	c2) State research		63
	a3) Embrapa national programs	Crops (3)	38
	b3) Embrapa regional centers		75
	c3) State research		29

Continued

Table A.3 The Brazilian experience on agricultural research impact evaluation (IRR)—Cont'd

Authors and Year	Location (Country, State, Center, etc.)	Commodity/Level	IRR (*)
26. Avila & Evenson (1995)	Embrapa Grain Research	Wheat Soybeans Maize Rice	40 58 37 40
27. Oliveira and Santos (1997)	Goat Research Center, Embrapa	Aggregate	24
28. Vilela, Morelli, and Makishima (1997)	Vegetables Research Center, Embrapa	Carrots research	36
29. Pereira and Santos (1998)	Cotton Research Center, Embrapa	Aggregate	15
30. Cançado Júnior, Lima, and Rufino (2000)	State Minas Gerais	Aggregate	32
31. Almeida, Avila, and Wetzel (2000)	Embrapa Research	Soybeans breeding program	69
32. Ambrosi (2000)	Wheat Research Center, Embrapa	Aggregate	88–143
33. Almeida and Yokoyama (2001)	Rice and Beans Research Center, Embrapa	Upland rice breeding program	93–115

*Estimations of average internal rate of return (IRR).
Source: Avila (2002).

Table A.4 Other Brazilian agricultural research impact evaluations (MIRR)

Authors and Year	Location (Country, Region, Center, Project . . .)	Commodity or Level	MIRR (*)
34. Evenson (1982)	Brazil	Aggregated	69
35. Silva (1984)	Brazil	Aggregated	60
36. Pinazza et al. (1984)	State of São Paulo, Brazil	Sugar cane	35
37. Ayres (1985)	Brazil State of Paraná State of São Paulo State of Santa Catarina State of Rio Grande Sul	Soybeans	46 51 23 31 53
38. Evenson and Cruz (1989a)	Brazil	Wheat Maize Soybeans	39 30 50
39. Evenson (1990a)	Brazil: Field crops	Field crops	41–141
40. Evenson (1990b)	Brazil: Center/South	Field crops Perennial crops	68–75 71–78

*Estimations of marginal internal rate of return (MIRR).
Source: Avila (2002).

Table A.5 The agricultural research impact in Hispanic countries in LAC

Authors	Country	Commodity/Level	Rates of Return (%)
41. Barletta (1971)	Mexico	Wheat Potato Maize Other crops	74–104 69 26–59 54–82
42. Himes (1972)	Peru	Maize	65
43. Ardila (1973)	Colombia	Rice	58
44. Montes (1973)	Colombia	Soybean	79
45. Trujillo (1974)	Colombia	Wheat	12
46. Jaramillo (1976)	Colombia	Barley	53
47. Pena (1976)	Colombia	Potato	68
48. Aragón and Forero (1976)	Colombia	Oil palm	30
49. Scobie and Posada (1977)	Colombia	Rice	87
50. Pazols (1981)	Chile	Rice	16–94
51. Yarrazaval R. (1982)	Chile	Wheat Maize	21–28 36–34
52. Martinez (1983)	Panama	Maize	47–325
53. Norton (1987)	Peru	Beans Maize Potato Rice Wheat Other crops	14–24 10–31 22–48 17–44 18–36 17–38
54. Mendoza (1987)	Ecuador	Potato Rice Soybeans Oil palm	28 44 17 32
55. Romano (1988)	Colombia	Crops and livestock** Crops and livestock	72–85 141

Continued

Table A.5 The agricultural research impact in Hispanic countries in LAC—Cont'd

Authors	Country	Commodity/Level	Rates of Return (%)
56. Scobie (1988)	Honduras	Fruit, nut Other crops	16–93 17–76
57. Cordomi (1989)**	Argentina	Aggregated Other crops	41 33–38
58. Echeverría (1989)	Uruguay	Rice	52
59. Evenson and Cruz (1989b)	PROCISUR Region: Southern Cone of South America	Wheat Maize Soybeans	110 191 179
60. Ruiz de Londono (1990)	Peru / Colombia	Beans	15–29
61. Traxler (1990)	Mexico	Wheat	22–24
62. Pino (1991)	Ecuador	Wheat Potato Soft Maize Beans	29 29 3 5
63. Palomino and Echeverría (1991)	Ecuador	Rice	34
64. Taxler (1992)	Mexico	Wheat	15–23
65. Cruz and Avila (1992)	Andean region	Aggregated	24
66. Vivas, Zuluaga, and Castro (1992)	Colombia	Sugar cane	13
67. Racines (1992)	Ecuador	Oil Palm Soybeans	32 35
68. Palomino and Norton (1992)	Ecuador	Flint maize	54
69. Byerlee (1994)	Latin America/ Caribbean Mexico	Wheat Wheat	81 53

Continued

Table A.5 The agricultural research impact in Hispanic countries in LAC—Cont'd

Authors	Country	Commodity/Level	Rates of Return (%)
70. Cap (1994)	Argentina	Beef	74
		Dairy	55
		Maize	77
		Potato	69
		Wheat	67
		Other crops	54–59
71. Macagno (1994)	Argentina	Maize	47
		Wheat	32
		Other crops	34
72. Penna (1994)	Argentina	Potato	53–61
73. Romano, Bermeo, and Torregrosa (1994)	Colombia	Sorghum	70
74. Byerlee (1995)	Latin America	Wheat	82
75. Fonseca (1996)	Peru	Potato	26
76. Ortiz (1996)	Peru	Potato	30
77. Farfán (1999)	Colombia	Coffee	21–31
78. Manzano (1999)	Ecuador	Rice	58
79. Amores (1999)	Ecuador	Cocoa	31
80. Goméz (2001)	Colombia	Oil palm	—

*Average internal rate of return.
**Estimations of marginal internal rate of return (MIRR).
Source: Colombia and Ecuador, authors; other countries, Alston et al. (2000).