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Investing in Agricultural Supply

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The capacity to increase the supply of food and other agricultural products is of obvious importance to developing countries, particularly those faced with rapidly growing populations. Historically, growth in agricultural supply has passed through stages. As long as it is possible to bring new areas under cultivation at low cost, increased agricultural supply is achieved primarily through the expansion of cultivated area. As low-cost land conversion possibilities are exhausted, higher cost sources of growth are exploited, notably investments in irrigation and drainage. Investment in agricultural research and extension systems can also produce fairly low-cost growth in agricultural supply, as documented by a large number of studies. These studies have also revealed strong interactions of improved agricultural technology with soil and climate factors, which impede the diffusion of technology across broad regions. Agricultural experiment stations and associated extension services must, therefore, be located to serve specific subregions if their growth-producing potential is to be realized fully.[1]

Agricultural research systems are complex institutions. The formidable public good problems encountered in most branches of scientific research are particularly acute in the case of agriculture. Patent laws protect mechanical and chemical innovations more easily than biological ones. Hence crop and livestock research -- plant breeding, phytopathology, entymology, agronomy, soil science, animal nutrition, etc. -- are today primarily public sector activities. The amount and type of agricultural research provided by the public sector in a given country is influenced by a number of factors, including the supply of research personnel and public funds, the perceived

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opportunities for productive research and the political strength of those who stand to gain from it, whether as agricultural producers, input suppliers or consumers. Today the industrialized countries retain their historic dominance in worldwide agricultural research investment, but recent decades have witnessed substantial growth in agricultural research in developing countries. In addition to the national systems, many of which have grown rapidly, nine International Agricultural Research Centers (IARC's) have been established beginning with the forerunner of CIMMYT (The International Wheat and Maize Improvement Center) in Mexico in the 1940s. International aid donors have provided considerable funding for national agricultural research systems as well as the IARC's.[2]

In spite of the importance of institutions devoted to the production and diffusion of improved agricultural technology, no international body presently collects and reports data on investment in these activities on an international basis. Only three comprehensive international surveys of investment in agricultural research and extension have been made to date. The results of the first survey were reported in this journal (Kislev and Evenson) in 1975. That survey, based on a questionnaire distributed in 1970, reported consistent comparisons of investment in research and extension by country. A follow-up to this first study entailed a second survey questionnaire plus visits to many national research and extension bureaus and ministries. This survey was reported in Boyce and Evenson, 1975. The third survey, conducted in 1980 and 1981, again based on a questionnaire, a review of reports, an analysis of scientific publications and some personal visits, is reported in the present paper.

Section I of the paper provides a descriptive summary of expenditure and personnel data by political and geo-climate regions. (An Appendix reports data by country). We also report investment by commodity for twenty-six major developing countries. Section II reports a statistical analysis of

the public sector investment motives which guide investment in national programs. We investigate the effects of the relative prices of research and extension personnel, the economic value of target commodities, the openness of trade, and the possibilities for free-riding and appropriation of gains as factors influencing investment. A final section discusses some policy implications of our findings.

I. Public Sector Agricultural Research and Extension

In 1975, Boyce and Evenson's National and International Agricultural Research and Extension Programs provided the most comprehensive data on international agricultural research and extension assembled to date. The data presented in this paper are a continuation of that work. We have collected data on expenditures and manpower which make it possible for us to extend Boyce and Evenson's time series to 1980. The data can now provide us, therefore, with a twenty-year perspective on the worldwide allocation of resources to agricultural research and extension. We also present more data on research emphasis by commodity than has previously been available.

In assembling the data for this paper, we encountered many of the same problems which Boyce and Evenson faced in compiling data for the earlier work, e.g., 'quality' variation in scientists, currency conversion problems, and conflicting or inconsistent data. Since almost all of the 1959-74 data in this paper have been taken from the 1975 work, we have tried to use the same or similar procedures and standards. Wherever possible, the designation of research scientist was limited to those possessing advanced degrees. In all cases where we had new data, expenditures were converted to U.S. dollars using official exchange rates and were then inflated to 1980 dollars using a general wholesale price index. The same price index was used to convert the expenditure data taken from Boyce and Evenson as well as to convert data on the value of

agricultural production and trade.

While most of the 1959-74 data in the present study were taken from Boyce and Evenson, we did obtain some new data that enabled us either to fill in the time series for some countries for which there had previously been no data or to replace some estimated or questionable figures with more reliable data. In some cases there was inconsistency between old and new data, and we had to make judgments about the reliability of various sources.

A. Expenditure and Manpower Data

Table 1 and Appendix Table 1 provide constructed time-series data on expenditures and manpower for agricultural research. The data in Table 1 are summarized by geographic region for three time periods -- 1959, 1970, and 1980. Appendix Table 1 presents expenditure and manpower data for 106 countries for eight time periods, the three year intervals from 1959 through 1980. Table 2 and Appendix Table 2 report comparable data for extension. Unfortunately, we were unable to obtain as much new extension data, and, therefore, we could not add significantly to Boyce and Evenson's extension time series for several regions.[3] Table 3 summarizes the percentage distribution of research and extension expenditures and manpower by subregion. Taken together, these tables portray the major changes which have occurred in spending patterns over the last twenty years.

We estimate that total public sector agricultural research spending in 1980 was approximately 7.4 billion dollars. Public sector extension spending was approximately 3.6 billion dollars. These data do not include spending by the International Agricultural Research Centers (IARC's) of approximately 120 million dollars in 1980. National research systems have increased real spending by a multiple of 3.68 since 1959 (and by a multiple of 1.4 since 1970). Scientist man-years have increased by a multiple of 3.14, reflecting the rise in

Table 1: Agricultural Research Expenditures and Manpower

Region/Subregion	Expenditures (000 Constant 1980 US$) 1959	1970*	1980	Manpower (Scientist Man-Years) 1959	1970*	1980
Western Europe	274,984	918,634	1,489,588	6,251	12,547	19,540
Northern Europe	94,718	230,135	409,527	1,818	4,409	8,027
Central Europe	141,054	563,334	871,233	2,888	5,721	8,827
Southern Europe	39,212	125,165	208,828	1,545	2,417	2,686
Eastern Europe and USSR	568,284	1,282,212	1,492,783	17,701	43,709	51,614
Eastern Europe	195,896	436,094	553,400	5,701	16,009	20,220
USSR	372,388	846,118	939,383	12,000	27,700	31,394
North America and Oceania	760,466	1,485,043	1,722,390	8,449	11,688	13,607
North America	668,889	1,221,006	1,335,584	6,690	8,575	10,305
Oceania	91,577	264,037	386,806	1,759	3,113	3,302
Latin America	79,556	216,018	462,631	1,425	4,880	8,534
Temperate South America	31,088	57,119	80,247	364	1,022	1,527
Tropical South America	34,792	128,958	269,443	570	2,698	4,840
Caribbean and Central America	13,676	29,941	112,941	491	1,160	2,167
Africa	119,149	251,572	424,757	1,919	3,849	8,088
North Africa	20,789	49,703	62,037	590	1,122	2,340
West Africa	44,333	91,899	205,737	412	952	2,466
East Africa	12,740	49,218	75,156	221	684	1,632
South Africa	41,287	60,752	81,827	696	1,091	1,650
Asia	261,114	1,205,116	1,797,894	11,418	31,837	46,656
West Asia	24,427	70,676	125,465	457	1,606	2,329
South Asia	32,024	72,573	190,931	1,433	2,569	5,691
Southeast Asia	9,028	37,405	103,249	441	1,692	4,102
East Asia	141,469	521,971	734,694	7,837	13,720	17,262
China	54,166	502,491	643,555	1,250	12,250	17,272
World Total	2,063,553	5,358,595	7,390,043	47,163	108,510	148,039

*The 1970 figures are an average of data from 1968 and 1971.

Note: Data for this table are drawn from Appendix Table 1.

Table 2: Agricultural Extension Expenditures and Manpower

Region/Subregion	Expenditures (000 Constant 1980 US$) 1959	1970*	1980**	Manpower (Workers) 1959	1970*	1980**
Western Europe	234,016	457,675	514,305	15,988	24,388	27,881
Northern Europe	112,983	187,144	201,366	4,793	5,638	6,241
Central Europe	103,082	199,191	236,834	7,865	13,046	14,421
Southern Europe	17,950	71,340	76,105	3,330	5,704	7,219
Eastern Europe and USSR	367,329	562,935	750,301	29,000	43,000	55,000
Eastern Europe	126,624	191,460	278,149	9,340	15,749	21,546
USSR	240,705	371,475	472,152	19,660	27,251	33,454
North America and Oceania	383,358	601,950	760,155	13,580	15,113	14,966
North America	332,892	511,883	634,201	11,500	12,550	12,235
Oceania	50,466	90,067	125,954	2,080	2,563	2,731
Latin America	61,451	205,971	396,944	3,353	10,782	22,835
Temperate South America	5,741	44,242	44,379	205	1,056	1,292
Tropical South America	47,296	136,943	294,654	2,369	7,591	16,038
Caribbean & Central America	8,414	24,786	57,911	779	2,135	5,505
Africa	237,883	481,096	514,671	28,700	58,700	79,875
North Africa	84,634	176,498	172,910	7,500	14,750	22,453
West Africa	53,600	181,324	204,982	9,000	22,000	29,478
East Africa	39,496	86,096	106,030	9,000	18,750	24,211
South Africa	60,153	37,178	30,749	3,200	3,200	3,733
Asia	143,876	412,937	507,113	86,900	142,500	148,780
West Asia	28,211	97,315	119,780	7,000	18,800	16,535
South Asia	56,422	87,727	82,194	57,000	74,000	80,958
Southeast Asia	19,747	55,441	63,959	9,500	30,500	33,987
East Asia	39,496	172,454	241,180	13,400	19,200	17,300
China	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
World Total	1,427,913	2,722,564	3,443,489	177,521	294,483	349,337

*The 1970 figures are an average of data from 1968 and 1971.
**1974 data has been used where no data were available for 1980. In other cases, the 1980 data are averages for 1974-1980.

Note: Data for Latin America, Western Europe, and North America/Oceania are drawn from Appendix Table 2. Data for Eastern Europe and USSR, Africa and Asia are estimates.

expenditures per scientist over the period. The comparable multiples for extension spending and manpower are 2.50 and 2.05.

From Table 1 and Appendix Table 1 it is evident that the industrialized regions of the world -- Western Europe, Eastern Europe/USSR, North America/Oceania, and Japan -- continue to spend the most on agricultural research. In addition, China appears to have become, by 1970, one of the 'big spenders' in this area.[4] If one excludes China and Japan, expenditures for Asia in 1980 are approximately the same as those for Latin America and Africa. The expenditure shares presented in Table 3 reveal the declining importance of both North America/Oceania and Eastern Europe/USSR relative to the rest of the world, and the increasing importance of Western Europe, Latin America, and Asia. When China is included, Asia's share almost doubles between 1959 and 1980; without China it increases from 10.3 to 17.1 percent, and without both China and Japan it increases from 4 to 8 percent. Africa's share of total expenditures has remained virtually unchanged during the period indicating that while it is holding its own, the region has generally not experienced an expansion in its research program comparable to that of Latin America and Asia.

In Latin America, the research programs in Brazil and Mexico have experienced substantial growth. Brazil's share of expenditures for all of Latin America increased from around 14 percent in 1959 to 38 percent in 1980. During the same period, Mexico's share increased from 6 to 15 percent. By 1980, the two countries thus accounted for slightly over half of all research expenditures in Latin America. Argentina also invests a significant amount in research, but expenditures there have actually decreased, in dollar terms, since they reached a high point in 1974.

The two largest investors in agricultural research in Africa are Nigeria and South Africa. In 1959, South Africa accounted for approximately 33 percent of all research expenditures in Africa; by 1980 its share had dropped to 15 percent. Nigeria's expenditures, on the other hand, rose from 12 percent of the total for Africa in 1959 to 29 percent in 1980. As in Latin America, two countries account for almost 50 percent of all expenditures in the region.

Table 3: International Distribution of Public Sector Research and Extension Expenditures and Manpower

Region/Subregion	Share of Public Sector Agricultural Research Expenditures		Share of Scientific Manyears		Share of Extension Expenditures		Share of Extension Workers	
	1959	1980	1959	1980	1959	1980	1959	1980
Western Europe	13.3 (13.7)	20.2 (22.1)	13.3 (13.7)	13.2 (14.9)	16.4	15.6	9.0	8.0
Northern Europe	4.6 (4.7)	5.6 (6.1)	3.9 (4.0)	5.4 (6.1)	7.9	6.0	2.7	1.8
Central Europe	6.8 (7.0)	11.8 (12.9)	6.1 (6.3)	6.0 (6.8)	7.2	7.3	4.4	4.1
Southern Europe	1.9 (2.0)	2.8 (3.1)	3.3 (3.4)	1.8 (2.0)	1.3	2.3	1.9	2.1
Eastern Europe & USSR	27.5 (28.3)	20.2 (22.1)	37.5 (38.6)	34.9 (39.5)	25.7	21.0	16.3	15.0
Eastern Europe	9.5 (9.8)	7.5 (8.2)	12.1 (12.4)	13.7 (15.5)	8.9	7.8	5.3	5.9
USSR	18.0 (18.5)	12.7 (13.9)	25.4 (26.2)	21.2 (24.0)	16.8	13.2	11.0	9.1
North America & Oceania	36.9 (37.8)	23.3 (25.5)	17.9 (18.4)	9.2 (10.4)	26.8	22.4	7.6	4.0
North America	32.4 (33.2)	18.1 (19.8)	14.2 (14.6)	7.0 (7.9)	23.3	18.7	6.5	3.2
Oceania	4.5 (4.6)	5.2 (5.7)	3.7 (3.8)	2.2 (2.5)	3.5	3.7	1.1	0.8
Latin America	3.9 (4.0)	6.3 (6.9)	3.0 (3.1)	5.8 (6.6)	4.3	12.7	1.9	7.2
Temperate South America	1.5 (1.5)	1.2 (1.2)	0.7 (0.8)	1.0 (1.2)	0.4	1.4	0.1	0.4
Tropical South America	1.7 (1.8)	3.6 (4.0)	1.2 (1.2)	3.3 (3.7)	3.3	9.4	1.3	5.0
Caribbean & Central America	0.7 (0.7)	1.5 (1.7)	1.1 (1.1)	1.5 (1.7)	0.6	1.9	0.5	1.8
Africa	5.8 (5.9)	5.7 (6.2)	4.1 (4.2)	5.5 (6.2)	16.7	14.8	16.2	20.7
North Africa	1.0 (1.0)	0.8 (0.9)	1.2 (1.3)	1.6 (1.8)	5.9	4.8	4.2	5.2
West Africa	2.2 (2.2)	2.8 (3.0)	0.9 (0.9)	1.7 (1.9)	3.8	6.2	5.1	7.9
East Africa	0.6 (0.6)	1.0 (1.1)	0.5 (0.5)	1.1 (1.2)	2.8	2.9	5.1	6.6
South Africa	2.0 (2.1)	1.1 (1.2)	1.5 (1.5)	1.1 (1.3)	4.2	0.9	1.8	1.0
Asia	12.7 (10.3)	24.3 (17.1)	24.2 (22.2)	31.6 (22.5)	10.2	13.5	49.0	45.1
West Asia	1.2 (1.2)	1.7 (1.9)	1.0 (1.0)	1.6 (1.8)	2.0	2.9	3.9	6.3
South Asia	1.6 (1.6)	2.6 (2.8)	3.0 (3.1)	3.8 (4.4)	4.0	2.3	32.1	22.4
Southeast Asia	0.4 (0.4)	1.4 (1.5)	0.9 (1.0)	2.8 (3.1)	1.4	1.6	5.5	10.9
East Asia	6.9 (7.1)	9.9 (10.9)	16.6 (17.1)	11.7 (13.2)	2.8	6.7	7.5	5.5
China	2.6 -	8.7 -	2.7 -	11.7 -	n.a.	n.a.	n.a.	n.a.

Note: Numbers in parentheses are shares calculated excluding China from the total.
Figures in this table are based on data from Appendix Tables 1 and 2.

Although agricultural research in Asia is clearly dominated by Japan, China, and, to a lesser extent, India, several countries in the region have substantially increased their spending. Bangladesh, Indonesia, Malaysia, Pakistan, and Thailand have all expanded their research programs by large multiples since 1959. The growth in expenditures in these five countries accounts for most of the increase in Asia's share (excluding both Japan and China) of the world's total.

The patterns revealed by the scientist man-year (SMY) figures are somewhat different from those which characterize the expenditure figures. Eastern Europe/USSR and Asia accounted for over 60 percent of the world's SMY's in both 1959 and 1980 (this is true even if one excludes China). The share of Eastern Europe/USSR declined somewhat between 1959 and 1980, but it remains several times larger than that of either Western Europe or North America/Oceania, a reflection of the relative capital-intensity of the research program in these latter regions.[5]

Although Africa's share of world SMY's only increased from 4.1 to 5.5 percent during this period, SMY's in 1980 were over 4 times what they had been in 1959. Many African countries have gone through a post-colonial adjustment period during which highly paid British and French civil servants have been replaced by somewhat lower paid national scientists. Therefore, these countries have been able to increase the number of SMY's devoted to agricultural research at a faster rate than they have expanded expenditures.

The increase in the number of SMY's in Latin America follows the same pattern as the increase in expenditures. Tropical South America (Brazil) and the Caribbean/Central America (Mexico), have experienced the greatest increase. South Asia and Southeast Asia have both increased SMY's more slowly than expenditures.[6]

The international distribution of extension expenditures in 1980 was remarkably even, as shown in Table 3. The industrialized regions were spending slightly more than other regions, but differences in expenditure levels are much less

significant than in the case of research. This points out quite clearly that the industrialized regions have placed more emphasis on research than on extension while the developing regions have tended to do the opposite. The most dramatic change between 1959 and 1980 was the expansion of extension expenditures in Latin America (Latin America's share increased from 4.3 percent in 1959 to 12.7 percent in 1980). Africa's share decreased slightly during the period, but the region continues to spend more on extension than either Latin America or Asia (excluding China).

The data on extension workers show a very different distribution pattern. In 1959, almost half of the world's extension workers were in Asia, and this share was still substantial in 1980, 45.1 percent. If extension data were available for China, Asia's share would undoubtedly be much larger. Latin America's share of extension workers increased from 1.9 to 7.2 percent, led primarily by a substantial increase in the share of the countries of Tropical South America (Brazil).

B. Measures of Expenditure and Manpower Intensities

In Table 4, expenditures on research and extension are given as a percent of the value of agricultural product. We have calculated this measure for five country groups as well as for the geographic regions. Countries were assigned to a group based on the classification used by the World Bank in its World Development Report, 1980. The only change we made was to divide the middle-income category into two parts -- middle-income developing and semi-industrialized -- using a per capita income level of $1050 as the dividing line between the two classes.[7]

All regions increased the percent of agricultural product invested in agricultural research between 1959 and 1980. Eastern Europe, the USSR, and North America, however, experienced declines in the ratios during the 1970s. This measure is as low as it is for North America primarily because the United States has been spending only about 1 percent of the value of its agricultural product

Table 4: Research & Extension Expenditures as a Percent of the Value of Agricultural Product

Subregion	Public Sector Agricultural Research Expenditures			Public Sector Agricultural Extension Expenditures		
	1959	1970	1980	1959	1970	1980
Northern Europe	.55	1.05	1.60	.65	.85	.84
Central Europe	.39	1.20	1.54	.29	.42	.45
Southern Europe	.24	.61	.74	.11	.35	.28
Eastern Europe	.50	.81	.78	.32	.36	.40
USSR	.43	.73	.70	.28	.32	.35
Oceania	.99	2.24	2.83	.42	.76	.98
North America	.84	1.27	1.09	.42	.53	.56
Temperate South America	.39	.64	.70	.07	.50	.43
Tropical South America	.25	.67	.98	.34	.71	1.19
Caribbean & Central America	.15	.22	.63	.09	.18	.33
North Africa	.31	.62	.59	1.27	2.21	1.71
West Africa	.37	.61	1.19	.58	1.24	1.28
East Africa	.19	.53	.81	.67	.88	1.16
South Africa	1.13	1.10	1.23	1.64	.67	.46
West Asia	.18	.37	.47	.25	.57	.51
South Asia	.12	.19	.43	.20	.23	.20
Southeast Asia	.10	.28	.52	.24	.37	.36
East Asia	.69	2.01	2.44	.19	.67	.85
China	.09	.68	.56	n.a.	n.a.	n.a.
Country Group*						
Low-Income Developing	.15	.27	.50	.30	.43	.44
Middle-Income Developing	.29	.57	.81	.60	1.01	.92
Semi-Industrialized	.29	.54	.73	.29	.51	.59
Industrialized	.68	1.37	1.50	.38	.57	.62
Planned	.33	.73	.66	-	-	-
Planned - excluding China	.45	.75	.73	.29	.33	.36

*For definition of Country Groups see Note 7.

on research (0.98 percent in 1980 compared to, for example, 3.34 in Japan, 3.03 in Australia, 2.26 in New Zealand, and 2.22 in Canada). One should be somewhat cautious about drawing conclusions about the situation in Eastern Europe and the USSR since the recent data for these countries are estimates, but it appears that the relative lack of expansion which currently characterizes the U.S. system is present in the systems of Eastern Europe and the USSR as well.

While almost all regions have increased the percent of agricultural product invested in research, the basic relationship between the industrialized and developing countries has not changed very much since 1959. It is still the case that the more affluent a country is, the more it is apt to spend on research relative to the value of its agricultural product. This relationship has changed somewhat between middle-income developing and semi-industrialized countries with the middle-income countries achieving roughly the same ratios as the semi-industrialized countries by 1980.

The data for extension show that generally the lower income countries spend a larger share of the value of agricultural product on extension than on research, and higher income countries spend a smaller share. Five regions -- North, West, and East Africa, Tropical South America, and West Asia -- are investing more in extension than in research. By 1980, however, low-income developing countries as whole were actually spending a slightly higher percentage of the value of their agricultural product on research than on extension. This indicates a major change in priorities since 1959, when the percentage for extension expenditures was twice as high as that for research expenditures.

Table 5 presents figures on SMY's and extension workers per 10 million dollars (constant 1980) of agricultural product by geographic subregion and country group. In general, the industrialized countries engage more scientists and fewer (many fewer) extension workers for every dollar of agricultural

Table 5: Research and Extension Manpower Relative to the Value of Agricultural Product

	SMY's Per 10 Million (Constant 1980) Dollars Agricultural Product			Extension Workers per 10 Million (Constant 1980) Dollars Agricultural Product		
Subregion	1959	1970	1980	1959	1970	1980
North Europe	1.05	2.01	3.14	2.76	2.56	2.61
Central Europe	.80	1.21	1.56	2.19	2.77	2.73
Southern Europe	.93	1.17	.96	2.00	2.76	2.69
Eastern Europe	1.44	2.97	2.84	2.36	2.88	3.13
USSR	1.38	2.37	2.34	2.26	2.33	2.50
Oceania	1.91	2.64	2.43	2.26	2.17	2.11
North America	.84	.89	.84	1.44	1.31	1.08
Temperate South America	.46	1.15	1.32	.26	1.19	1.26
Tropical South America	.41	1.41	1.77	1.71	3.95	6.46
Caribbean & Central America	.53	.86	1.20	.82	1.53	3.12
North Africa	.91	1.44	4.24	18.83	28.45	22.23
West Africa	.33	.61	1.42	7.61	14.01	18.08
East Africa	.32	.77	1.76	16.28	22.41	26.64
South Africa	1.90	1.96	2.47	8.73	5.94	5.62
West Asia	.33	.84	.88	4.39	7.25	6.54
South Asia	.50	.65	1.29	20.83	19.51	19.53
Southeast Asia	.47	1.28	2.07	9.81	13.07	19.72
East Asia	3.80	5.29	5.72	6.57	7.05	6.13
China	.22	1.66	1.49	n.a.	n.a.	n.a.
Country Group						
Low-Income Developing	.43	.67	1.40	18.14	18.61	20.43
Middle-Income Developing	.69	1.31	2.40	8.89	14.68	15.98
Semi-Industrialized	.70	1.21	1.36	2.80	4.95	5.21
Industrialized	1.24	1.71	1.85	2.37	2.31	2.12
Planned	1.02	2.27	2.13	-	-	-
Planned excluding China	1.40	2.54	2.50	2.29	2.49	2.63

product than do the developing countries. The number of SMY's per dollar of production is highest for the planned and middle-income developing economies; the number of extension workers per dollar is highest for low-income developing countries. SMY's relative to the value of agricultural product have been increasing over time in almost all regions and for almost all country groups. Extension workers relative to agricultural product have changed little or decreased somewhat in Western Europe and North America/Oceania and have tended to increase in the regions of Latin America, Asia and Africa. Most regions of Asia and Africa have very high levels of extension workers per dollar of product.

Although Table 4 indicated that the developing countries may be beginning to shift their priorities from extension to research, Table 5 shows that the number of extension workers relative to the value of agricultural product has increased steadily since 1959 for developing countries.

C. Expenditures Per Manpower Unit

The data on expenditures relative to manpower reported in Table 6 show immediately that, without exception, expenditures per SMY are substantially higher than those per extension worker. Not only are salaries for research scientists higher than those for extension workers, but the level of support (laboratory facilities, technicians, etc.) required to maintain an effective research program is many times that required to maintain an effective extension program.

The levels of expenditures per SMY in 1980 were highest in North America/Oceania and lowest in Asia and Eastern Europe/USSR. This was also the case in 1959. Expenditures per SMY have been decreasing in Africa indicating that the cost of a research scientist has been declining, probably as the result of a shift from expatriate to indigenous personnel. It is interesting to note that

Table 6: Agricultural Research/Extension Expenditures per SMY/Extension Worker

Region/Subregion	Research Expenditures per SMY (000 Constant 1980 US$)			Extension Expenditures per Extension Worker (000 Constant 1980 US$)		
	1959	1970	1980	1959	1970	1980
Western Europe	44	73	76	15	19	18
Northern Europe	52	52	51	24	33	32
Central Europe	49	98	99	13	15	16
Southern Europe	25	52	78	5	13	11
Eastern Europe & USSR	32	29	29	13	13	14
Eastern Europe	34	27	27	14	12	13
USSR	31	31	30	12	14	14
North America & Oceania	90	127	127	28	40	51
North America	100	142	130	29	41	52
Oceania	52	85	117	24	35	46
Latin America	56	44	54	18	19	18
Temperate South America	85	56	53	28	42	34
Tropical South America	61	48	56	20	18	18
Caribbean & Central America	28	26	52	11	12	11
Africa	62	65	53	8	8	6
North Africa	35	44	27	11	12	8
West Africa	108	97	83	6	8	7
East Africa	58	72	46	4	5	4
South Africa	59	56	50	19	12	8
Asia	23	38	39	2	3	3
West Asia	53	44	54	4	5	7
South Asia	22	28	34	1	1	1
Southeast Asia	20	22	25	2	2	2
East Asia	18	38	43	3	9	14
China	43	41	37	n.a.	n.a.	n.a.
Country Group						
Low-Income Developing	34	40	47	2	2	2
Middle-Income Developing	42	44	47	7	7	6
Semi-Industrialized	41	45	46	10	10	11
Industrialized	55	80	93	16	25	29
Planned	33	32	31	-	-	-
Planned excluding China	31	25	30	13	13	14

while there are significant differences in expenditures per SMY between the industrialized countries, planned economies, and other countries, there are no significant differences between the low- and middle-income developing and semi-industrialized countries.

Extension expenditures per extension worker in 1980 were also highest in North America/Oceania. They were lowest in Asia and Africa. The breakdown by country group shows a strong correlation between development level and expenditures per extension worker. It should also be noted that expenditures per extension worker did not change for low- and middle-income developing and semi-industrialized countries between 1959 and 1980. In fact, it is only the industrialized countries which have increased expenditures per worker.

We will return to the issue of prices and quality in Section II of the paper. It is worth noting at this point, however, that the differences in expenditures per manpower unit summarized in Table 6 go a long way toward explaining the investment patterns observed in the earlier tables. Most developing countries have been able to train extension workers at low cost and to staff extension programs at very low costs per extension worker. This is particularly true in Asia, notably in South and Southeast Asia. The same cannot be said for researchers. The capacity to train researchers at an advanced level was practically non-existent in most developing countries in 1959. Most developing countries faced very high training costs for scientists (usually trained abroad) and very high costs of operating research programs. The African countries in particular faced high costs. This situation has changed somewhat since 1959, of course, but researchers are still costly for most developing countries. India, the Philippines, Brazil, Mexico and a few other countries have developed the capacity to produce doctorates in the agricultural sciences, but this capacity is quite limited. Thus even in 1980 the costs of operating research programs continued to be high for the developing world.

D. Investment by Geo-Climate Region

Tables 7, 8 and 9 organize our data by geo-climate regions as defined by Papadakis, 1966. This organization provides a clearer perspective on the likely contribution of research and extension to agricultural supply growth (as does the commodity organization provided in latter tables). Prior work has shown that improved agricultural technology is highly location specific and that insofar as it is transferred from one country to another, it is transferred within major geo-climate regions.[8] Thus if a geo-climate region is receiving little research attention, it is unlikely to be realizing high rates of supply growth via technological change. This is likely to be the case even if it is investing heavily in extension programs. In their early implementation, extension programs can have a substantial "once-for-all" effect on agricultural supply by bringing about efficiency gains in the presence of technological slack. But for long-run, sustained extension contributions to growth, a flow of extendable technology must be forthcoming.

Table 7 shows that the major developing country geo-climate regions, the tropical and sub-tropical, have realized significant gains in terms of percentage of both research spending and scientific manpower. The tropical zones have also increased their share of the world's extension resources and workers. This shift has come largely at the expense of the steppe climate zones in research and all developed regions in extension.

Table 8 shows that research intensities have increased in all of the subregions of the tropical through sub-tropical climate zones and that those subregions with lowest research emphasis in 1959 have generally realized the largest relative gains. This is quite encouraging from the perspective of potential supply growth. Nonetheless, it remains the case even in 1980 that several major subregions of the world are investing less than one half of one percent of the value of agricultural product in research.

Table 7: International Distribution of Public Sector Research and Extension Expenditures and Manpower, by Geo-Climate Region and Subregion

Geo-Climate Region/Subregion	Share of Public Sector Agricultural Research Expenditures 1959	1980	Share of Scientific Manyears 1959	1980	Share of Extension Expenditures 1959	1980	Share of Extension Workers 1959	1980
1 Tropical	5.2	8.9	5.1	9.7	12.4	17.4	28.6	37.4
1.1 Humid Semi-Hot Equatorial	1.7	2.9	1.3	3.0	4.1	4.4	7.5	11.6
1.2 Humid Semi-Hot Tropical	.2	.2	.3	.2	.2	.3	.3	.2
1.3 Dry Semi-Hot Tropical	.2	.2	.2	.2	.1	.2	.1	.4
1.4 Hot Tropical	1.1	1.6	1.2	2.0	2.3	3.2	6.0	8.7
1.5 Semi-Arid Tropical	.5	.7	.3	.4	1.5	2.2	1.3	1.8
1.7 Humid Tierra Templada	1.1	2.1	.8	1.9	2.6	5.7	2.4	5.0
1.8 Dry Tierra Templada	.1	.2	.1	.2	.5	.6	1.3	1.5
1.9 Cool Winter Hot Tropical	.5	1.1	.9	1.7	1.1	.8	9.8	8.2
2 Tropical Highlands	1.8	1.7	1.5	2.0	4.2	2.3	4.7	5.1
2.1 Semi-Tropical Tierra Fria	1.7	1.6	1.5	1.8	4.2	2.2	4.5	4.6
2.2 Low Tierra Fria	0	.08	0	.2	0	.04	0	.3
2.3 Medium Tierra Fria	.1	.02	.01	.06	.04	.09	.2	.2
3 Desert	.9	1.8	1.2	3.1	2.3	2.1	4.4	4.3
3.1 Hot Tropical Desert	.02	.04	.02	.06	.02	.09	.02	.1
3.2 Hot Subtropical Desert	.53	.7	.9	1.7	2.1	1.8	4.1	3.8
3.4 Cool Subtropical Desert	.01	.01	.02	.02	.08	.06	.08	.07
3.7 Continental Desert	.34	1.0	.3	1.3	.1	.2	.3	.3
4 Subtropical	2.5	6.9	3.3	8.3	2.5	4.5	14.3	11.4
4.1 Humid Subtropical	1.7	5.6	1.9	7.1	.8	3.5	.6	1.9
4.2 Monsoon Subtropical	.4	.6	.8	.7	1.0	.5	8.4	5.9
4.3 Hot Semi-Tropical	.3	.6	.8	.5	.6	.4	5.2	3.6
4.4 Semi-Hot Semi-Tropical	.1	.1	.07	.04	.1	.1	.04	.03
5 Pampean	1.5	1.1	.8	.8	.5	1.2	.1	.1

Table 7: International Distribution of Public Sector Research and Extension Expenditures and Manpower, by Geo-Climate Region and Subregion (continued)

Geo-Climate Region/Subregion	Share of Public Sector Agricultural Research Expenditures 1959	1980	Share of Scientific Manyears 1959	1980	Share of Extension Expenditures 1959	1980	Share of Extension Workers 1959	1980
6 Mediterranean	9.9	10.4	9.9	7.8	11.7	11.9	11.1	11.5
6.1 Subtropical Mediterranean	2.8	3.0	2.3	1.9	3.1	3.3	2.9	2.6
6.2 Marine Mediterranean	.6	.4	.7	.4	1.1	.5	.5	.5
6.5 Temperate Mediterranean	.8	1.4	1.4	1.0	1.1	1.7	1.7	2.6
6.7 Continental Mediterranean	3.1	2.9	3.3	2.2	2.4	2.9	2.4	2.5
6.8 Subtropical Semi-arid Mediterranean	2.6	2.6	2.2	2.2	4.0	3.5	3.5	3.2
6.9 Continental Semi-arid Mediterranean	.01	.03	.005	.02	.01	.04	.05	.05
7 Marine	17.8	21.2	17.8	19.9	20.8	17.1	10.2	9.7
7.1 Warm Marine	.2	.2	.1	.1	.1	.1	.04	.02
7.2 Cool Marine	4.4	6.1	3.3	4.9	5.0	4.9	1.7	1.6
7.6 Cool Temperate	11.4	12.7	12.0	12.3	12.9	9.6	7.0	6.9
7.7 Cold Temperate	1.9	2.2	2.4	2.7	2.8	2.4	1.4	1.3
8 Humid Continental	24.4	24.5	27.8	22.8	15.6	19.3	12.3	8.6
8.1 Warm Continental	7.8	10.9	11.8	12.1	3.8	6.4	5.0	3.8
8.2 Semi-Warm Continental	15.7	13.0	14.7	9.7	10.9	12.2	6.8	4.2
8.3 Cold Continental	.9	.7	1.3	1.1	.9	.7	.6	.6
9 Steppe	36.0	23.6	32.6	25.5	30.0	24.2	14.3	12.0
9.2 Semi-Warm Steppe	19.6	13.3	18.9	14.8	16.3	14.0	8.3	6.9
9.3 Cold Steppe	14.0	9.1	11.9	9.0	11.4	9.0	5.2	4.3
9.4 Temperate Steppe	2.4	1.2	1.8	1.8	2.3	1.2	.8	.8

Table 8: Research and Extension Expenditures as a Percent of the Value of Agricultural Product, by Geo-Climate Region and Subregion

Geo-Climate Region/Subregion	Public Sector Agricultural Research Expenditures			Public Sector Agricultural Extension Expenditures		
	1959	1970	1980	1959	1970	1980
1 Tropical	.21	.42	.72	.35	.59	.68
1.1 Humid Semi-Hot Equatorial	.21	.40	.72	.35	.49	.52
1.2 Humid Semi-Hot Tropical	.28	.33	.56	.16	.42	.44
1.3 Dry Semi-Hot Tropical	.30	.56	.62	.15	.24	.28
1.4 Hot Tropical	.24	.45	.69	.36	.75	.68
1.5 Semi-Arid Tropical	.37	.73	1.13	.79	1.84	1.79
1.7 Humid Tierra Templada	.25	.63	.91	.41	.74	1.21
1.8 Dry Tierra Templada	.12	.43	.53	.44	.68	.83
1.9 Cool Winter Hot Tropical	.10	.16	.49	.17	.20	.18
2 Tropical Highlands	.44	.59	.83	.73	.56	.54
2.1 Semi-Tropical Tierra Fria	.51	.67	.90	.85	.65	.59
2.2 Low Tierra Fria	-	-	.72	-	-	.18
2.3 Medium Tierra Fria	.04	.13	.17	.05	.05	.27
3 Desert	.15	.53	.58	.26	.51	.34
3.1 Hot Tropical Desert	.12	.89	.74	.11	.52	.89
3.2 Hot Subtropical Desert	.20	.35	.57	.55	.99	.74
3.4 Cool Subtropical Desert	1.03	1.58	1.03	4.47	5.93	3.16
3.7 Continental Desert	.10	.66	.58	.02	.08	.58
4 Subtropical	.11	.54	.58	.07	.14	.18
4.1 Humid Tropical	.10	.66	.61	.03	.11	.18
4.2 Monsoon Subtropical	.11	.19	.40	.19	.22	.17
4.3 Hot Semi-Tropical	.14	.23	.54	.18	.25	.18
4.4 Semi-Hot Semi-Tropical	1.12	1.84	1.94	.94	.77	.74
5 Pampean	.48	.70	.80	.10	.50	.42
6 Mediterranean	.43	.89	.97	.35	.59	.54
6.1 Subtropical Mediterranean	.75	1.57	1.81	.57	.88	.94
6.2 Marine Mediterranean	.75	1.22	1.25	.88	.78	.67
6.5 Temperate Mediterranean	.12	.37	.44	.12	.30	.26
6.7 Continental Mediterranean	.36	.68	.75	.20	.39	.36
6.8 Subtropical Semi-Arid Mediterranean	.78	1.65	1.76	.83	1.27	1.15
6.9 Continental Semi-Arid Mediterranean	.15	.49	.73	.16	.67	.51
7 Marine	.47	.99	1.28	.38	.48	.50
7.1 Warm Marine	.61	1.14	2.26	.32	.35	.56
7.2 Cool Marine	.62	1.16	1.96	.49	.79	.77
7.6 Cool Temperate	.44	.98	1.14	.34	.40	.42
7.7 Cold Temperate	.41	.81	.95	.41	.47	.52
8 Humid Continental	.52	1.17	1.12	.23	.38	.43
8.1 Warm Continental	.37	1.12	1.03	.12	.27	.29
8.2 Semi-Warm Continental	.66	1.27	1.26	.31	.49	.57
8.3 Cold Continental	.43	.73	.70	.28	.32	.35
9 Steppe	.60	.97	.87	.34	.41	.44
9.2 Semi-Warm Steppe	.53	.88	.80	.30	.39	.40
9.3 Cold Steppe	.66	1.07	.99	.37	.44	.47
9.4 Temperate Steppe	1.35	1.51	1.50	.87	.67	.75

Table 9 reports intensity measures of research and extension manpower. There is, of course, a problem of quality comparability with these data inasmuch as scientists and extension workers in the tropical regions may be less well-trained than their counterparts in the humid continental regions. We have discussed this problem in earlier work and concluded that it is probably the case that the average number of years of graduate work is lower for scientists in less developed countries. Further, more of those years were spent in institutions of lower average prestige. We would caution, however, that at the Ph.D.-level -- which is our basic criterion for definition of a research scientist -- a good deal of comparability exists. The majority of the Ph.D.-level agricultural scientists in both the developing and developed countries studied at the same set of institutions. Although a similar, and perhaps greater, difference in quality of extension training exists, we have in our work attempted to achieve certain minimum definitions of training.

The differences in research manpower intensities between regions in 1980 were surprisingly small. The table shows remarkably large differences in extension manpower intensities, in favor of the tropical regions, as earlier noted for geographic regions in Table 5. Even if we allow for a major quality adjustment, these data suggest that the countries of the developing world are responding to price differentials between scientists and extension workers and that they percieve extension workers to be good substitutes for scientists in the production of agricultural supply growth.

E. Investment by Commodity

Data on research investment by commodity are extremely difficult to obtain. The agricultural ministries and research councils of many countries can provide aggregate data on expenditure and manpower for research programs, but they are not able to allocate expenditures or manpower to commodities. In view of the

Table 9: Research and Extension Manpower Relative to the Value of Agricultural Product, by Geo-Climate Region and Subregion

Geo-Climate Region/Subregion	SMY's per 10 Million Dollars Agricultural Product (Constant 1980$)			Extension Workers per 10 Million Dollars Agricultural Product (Constant 1980$)		
	1959	1970	1980	1959	1970	1980
1 Tropical	.47	.94	1.57	9.95	12.19	13.90
1.1 Humid Semi-Hot Equatorial	.38	.85	1.48	8.01	9.76	13.15
1.2 Humid Semi-Hot Tropical	.97	1.20	1.36	3.50	3.71	3.74
1.3 Dry Semi-Hot Tropical	.58	1.36	1.62	1.97	3.82	6.35
1.4 Hot Tropical	.62	1.13	1.72	11.47	15.53	17.50
1.5 Semi-Arid Tropical	.51	.89	1.44	9.04	14.72	13.92
1.7 Humid Tierra Templada	.41	1.27	1.70	4.74	8.09	10.10
1.8 Dry Tierra Templada	.31	.62	1.36	12.71	19.99	18.73
1.9 Cool Winter Hot Tropical	.47	.63	1.55	18.60	17.03	17.03
2 Tropical Highlands	.88	1.17	1.99	10.09	10.15	11.38
2.1 Semi-Tropical Tierra Fria	1.02	1.34	2.02	11.32	11.28	11.90
2.2 Low Tierra Fria	-	-	3.43	-	-	12.23
2.3 Medium Tierra Fria	.04	.16	.79	2.73	2.16	5.17
3 Desert	.46	1.41	2.04	6.24	8.97	6.52
3.1 Hot Tropical Desert	.35	1.48	2.58	.96	6.17	12.01
3.2 Hot Subtropical Desert	.74	1.15	2.95	12.99	18.21	15.10
3.4 Cool Subtropical Desert	4.12	6.32	4.52	55.42	79.23	34.88
3.7 Continental Desert	.23	1.61	1.43	.72	.97	.72
4 Subtropical	.33	1.37	2.04	5.39	5.31	4.45
4.1 Humid Subtropical	.25	1.62	1.54	.33	.61	.96
4.2 Monsoon Subtropical	.50	.66	.94	20.45	19.06	18.57
4.3 Hot Semi-Tropical	.52	.75	.86	18.41	17.57	15.14
4.4 Semi-Hot Semi-Tropical	1.84	2.26	2.19	4.32	3.54	3.17
5 Pampean	.58	1.19	1.24	.30	.57	.47
6 Mediterranean	.99	1.43	1.47	4.17	5.55	4.97
6.1 Subtropical Mediterranean	1.41	2.02	2.30	6.67	7.33	7.13
6.2 Marine Mediterranean	1.79	2.36	2.44	5.40	6.46	7.02
6.5 Temperate Mediterranean	.48	.71	.64	2.27	4.11	3.59
6.7 Continental Mediterranean	.89	1.35	1.17	2.48	3.11	2.98
6.8 Subtropical Semi-Arid Mediterranean	1.56	2.24	3.00	9.06	12.50	10.34
6.9 Continental Semi-Arid Mediterranean	.19	1.10	.83	6.88	8.52	6.56
7 Marine	1.06	2.00	2.42	2.29	2.86	2.72
7.1 Warm Marine	1.01	1.65	2.05	1.50	1.31	.86
7.2 Cool Marine	1.08	2.08	3.17	2.06	2.23	2.32
7.6 Cool Temperate	1.04	1.97	2.22	2.30	2.78	2.85
7.7 Cold Temperate	1.14	2.09	2.39	2.62	2.76	2.68
8 Humid Continental	1.35	2.18	2.10	2.24	2.40	1.82
8.1 Warm Continental	1.27	2.49	2.30	2.02	2.57	1.68
8.2 Semi-Warm Continental	1.40	1.89	1.88	2.43	2.26	1.89
8.3 Cold Continental	1.38	2.37	2.34	2.26	2.34	2.50
9 Steppe	1.24	2.01	1.93	2.04	2.13	2.08
9.2 Semi-Warm Steppe	1.16	1.91	1.78	1.93	2.00	1.92
9.3 Cold Steppe	1.28	2.01	1.97	2.10	2.17	2.14
9.4 Temperate Steppe	2.29	4.42	4.52	3.78	4.28	4.81

relevance of such data for policy we have developed a methodology for estimating the commodity orientation of research for 26 large developing countries. These countries account for more than 90 percent of the research undertaken in developing and semi-industrialized countries, excluding China.

Our methodology entails the following steps. First, we obtained through computer search of the Commonwealth Agricultural Bureau (CAB) Abstracts, a count of the scientific articles and books published by commodity orientation and by country for the periods 1972-5 and 1976-9. The CAB abstracts provide very extensive coverage of the world's agricultural science, and the search process provided reasonable data on publications by commodity. Research expenditures per publication vary, however, from commodity to commodity. Our second step, therefore, was to compare the data on publications and on research expenditures by commodity for Brazil where previous work (Evenson, 1982) provided us with good expenditure data by commodity. These data enabled us to "standardize" publications to obtain equivalent spending units.[9] Third, we allocated research expenditure budgets to commodities according to proportions of equivalent spending units. We thus obtained estimated research expenditures by commodity for each of the 26 countries. Note that our final series, presented in Appendix Table 4, is not a publication series. It is an expenditure series. Publications data (which are given in Appendix Table 3) were utilized only to allocate expenditures among commodities.

Table 10 summarizes our data in terms of research expenditures as a percent of the value of the commodity. Several observations may be readily made. First, expenditures on livestock research are generally quite high. Second, several commodities -- specifically cassava, sweet potatoes, and coconuts -- receive little research attention anywhere in the world. Other commodities -- field beans, groundnuts, cotton, sugar, potatoes, and even rice and maize -- receive modest research attention in Asia, as does maize in Latin America. Export crops -- citrus, coffee,

Table 10: Research as a Percent of the Value of Product, by Commodity, Average 1972-79 Period

Region/Zone	Wheat	Rice	Maize	Cotton	Sugar	Soybeans	Cassava	Field Beans	Citrus	Cocoa	Potatoes	Sweet Potatoes	Vegetables
Geographical Region													
Africa	1.30	1.05	.44	.23	1.06	23.59	.09	1.65	.88	2.75	.21	.06	1.56
Asia	.32	.21	.21	.17	.13	2.33	.06	.08	.51	14.17	.19	.08	.41
Latin America	1.04	.41	.18	.23	.48	.68	.19	.60	.57	1.57	.43	.19	1.13
Geo-Climate Zone													
Tropical	.64	.25	.31	.34	.23	1.24	.12	.42	.78	1.67	.32	.06	1.81
Tropical Highlands	.80	.24	.05	.05	.24	.30	.08	.09	.07	.39	.42	.18	.20
Desert	.72	.21	.11	.14	.19	1.30	.08	.25	.22	.54	.40	.41	.39
Subtropical	.45	.18	.25	.24	.17	.76	.05	.19	.57	2.44	.20	.10	.97
Pampean	.66	.36	.03	.24	1.15	1.68	0	.58	3.33	0	1.36	.49	0
Mediterranean	.21	.20	.11	.07	2.64	0	0	.39	.34	0	.08	1.54	.66
International Centers	.02	.02	.03	-	-	-	.02	.04	-	-	.08	-	-
All Countries	.51	.25	.23	.21	.27	1.06	.11	.32	.52	1.69	.29	.07	.73

Table 10: Research as a Percent of the Value of Product, Average 1972-79 Period (continued)

Region/Zone	Bananas	Coffee	Groundnut	Coconut	Beef	Pork	Poultry	Other Livestock
Geographical Region								
Africa	.27	3.12	.57	.07	1.82	2.56	1.99	1.81
Asia	.20	1.25	.12	.03	.65	.39	.32	.89
Latin America	.64	.92	.60	.10	.67	.60	1.12	.42
Geo-Climate Zone								
Tropical	.25	1.28	.32	.03	1.46	.96	1.96	1.09
Tropical Highlands	.08	.10	.10	.09	.80	.48	0	.21
Desert	.18	.27	.14	.03	.94	.61	1.34	.39
Subtropical	.78	1.47	.11	.05	.86	.50	.87	.89
Pampean	0	0	.54	0	.48	.84	0	.93
Mediterranean	.60	0	.31	0	.54	.91	.65	.33
International Centers	-	-	.005	-	.02	.02	-	-
All Countries	.27	1.18	.25	.04	1.36	1.25	1.64	.71

and cocoa -- are generally given heavy emphasis.[10]

Third, the international research centers are not large enough in terms of expenditures to alter this picture except in potatoes and possibly field beans. Many observers fail to realize that the IARC's are not very large relative to national systems.[11]

Two further indexes describing the character of research investment for the 26 countries are reported in Table 11. The first is a "congruity" index showing the relationship between research spending and commodity importance. It is defined as

$$C = 1 - \sum_i (R_i - C_i)^2$$

where R_i and C_i are the shares of commodity i in the research budget and in the total value of commodities produced respectively. This measure shows considerable variation across countries. The indexes reported in Table 11 do, however, show closer congruity between research and production than shown in the congruity indexes computed by Boyce and Evenson (1975) for earlier periods.

Table 11: Research-Commodity Congruity Index and Share of Basic Research in Total Research

Country/Region	Congruity Index Average 1972-75	Congruity Index Average 1976-79	Share of Basic Research Average 1972-75	Share of Basic Research Average 1976-79
Egypt	.905	.939	26.0	26.2
Ghana	.906	.912	24.9	28.1
Kenya	.861	.840	19.1	18.8
Nigeria	.668	.675	21,6	27.1
Sudan	.888	.900	23.1	22.0
Tanzania	.763	.747	25.9	30.5
Tunisia	.892	.938	34.7	42.1
Uganda	.733	.826	25.6	32.8
Africa	.911	.910	-	-
Bangladesh	.675	.716	18.2	17.8
India	.935	.912	23.2	25.2
Indonesia	.816	.878	31.0	33.5
Korea (South)	.908	.842	25.8	23.3
Malaysia	.662	.534	24.2	9.3
Pakistan	.909	.949	20.6	26.1
Philippines	.404	.574	11.8	17.8
Sri Lanka	.731	.666	31.5	29.3
Taiwan	.957	.980	22.2	19.2
Thailand	.919	.927	40.9	36.0
Turkey	.957	.908	26.3	28.4
Asia	.957	.948	-	-
Argentina	.962	.982	31.2	33.9
Brazil	.963	.982	22.1	24.6
Chile	.910	.950	29.2	24.8
Colombia	.968	.933	16.7	17.7
Mexico	.884	.854	16.1	14.8
Peru	.954	.938	16.2	17.7
Venezuela	.946	.874	27.7	27.2
Latin America	.981	.983	-	-
Geo-Climate Zone				
Tropical	.938	.935		
Tropical Highlands	.930	.908		
Desert	.948	.956		
Subtropical	.956	.959		
Pampean	.962	.982		
Mediterranean	.982	.951		
All Countries	.967	.959		
All Countries with International Centers	.969	.962		

The second measure reported in Table 11 is an index of the degree of "basicness" of research programs. It is computed from the publications data as the ratio of (standardized) publications unallocable to commodities to total publications. Independent data for Brazil, which show that the proportion of basic or general research in Brazil's program declined from roughly 40 percent in the 1950s to 20 percent in the 1970s (Evenson, 1982), are consistent with these data. Certainly these data do not lend substance to the complaint that agricultural research programs in the developing world are not applied. They are in fact very applied in orientation.

II. Determinants of Investment

A. General Discussion

The descriptive tables of the previous section provide a few insights into the investment motives of different countries. It appears, for example, that investment is related to the economic importance of agricultural commodities and of aggregate agricultural product. It also appears that developing countries in particular have attempted to substitute low cost extension skills for higher cost research skills. In this section we further examine the factors determining investment. Since we are relying on international data, we will not attempt to develop a detailed testable model of government behavior. That is difficult for even a single country, although several recent studies have attempted such models.[12]

For the purpose of the present statistical analysis, we assume that governments have a productivity growth objective. Actual resource allocation decisions are the outcome of a political process, the actors and nature of which vary from country to country, but in general there is a broad political and economic interest in generating low-cost growth in agricultural productivity. With this objective in mind, consider the options facing a typical developing country. It can produce agricultural growth by:

1. adding to the arable land stock by clearing, draining and irrigating land;

2. improving the existing arable land stock by draining, irrigating, leveling, terracing, etc.;

3. adding to the labor force in agriculture;

4. adding to the stock of animal and machinery capital;

5. utilizing more fertilizer and chemical inputs;

6. eliminating inefficiencies in resource allocation, caused for example by price distortions or land tenure patterns;

7. adding to farmers' human capital, through education and training programs;

8. investing in extension programs to diffuse existing but unused technology to farmers;

9. developing improved location-specific agricultural technology through research investment.

Each of these alternatives has its own cost configuration for producing growth, and these costs vary over time and between countries. Adding to the land stock, for example, is a low cost source of growth when a land frontier exists. As such opportunities are exhausted, more costly activities are required. Drainage of swamps and investment in irrigation can be quite costly, particularly when the "easy" projects, from an engineering standpoint, have been exhausted.

Growth can also be achieved by adding to the agricultural labor force, but since governments are interested in obtaining more product per capita, this is not a source of per capita growth. If animals, machines, fertilizer and plant protection chemicals are inexpensive, they can be low cost means of obtaining more growth. Generally, however, modern inputs are low cost sources of growth only when "compatible" biological technology is being produced.

Countries faced with growing demand for agricultural products are therefore forced to choose among options involving the expansion or improvement of the land stock, the expansion of the use of inputs such as fertilizer, and the

development and diffusion of improved technology. (They may also choose to change price policies or modify land tenure to stimulate growth.) The technology option itself has several dimensions. If agricultural technology is highly transferable between countries, a strategy of heavy investment in extension makes sense. Extension programs can "screen" internationally available technology for effectiveness and extend this technology to farmers.

A reading of early development literature and a perusal of aid agency budgets indicate that this technology transfer strategy was the chief agricultural development strategy during the 1950s and 1960s. It is fairly clear that this strategy has produced very little growth in spite of the fact that extension programs have been low cost. Technology simply isn't very transferable. As countries recognized this fact they began to expand agricultural research programs. These research programs faciliated a somewhat more sophisticated type of indirect transfer of technology. A country could benefit from the research programs of neighboring countries and international centers by adapting their research findings to its own geo-climate conditions. Depending on the degree of complementarity between its own research and that of its neighbors, a country may have an incentive to "free-ride" on its neighbors' research. That is, if a neighboring country is undertaking an active research program, the recipient country may find it feasible to invest in only a minimal adaptive research program. In the absence of good neighbors, the recipient country would have to spend more on research to achieve the same growth objective.

We would also expect the volume of international trade in a commodity to affect research investment in it. There are three reasons for this. First, traded commodities generally have higher elasticities of demand than untraded commodities. Hence an increase in supply will have a smaller price effect

for exported or imported commodities. Second, most governments tend to place high weights on earning or saving foreign exchange. Third, most developing countries have pursued price policies designed to provide urban consumers with low cost food. In many countries imports of foodgrains are used to achieve low food prices. The higher the import bill, the more vulnerable the country will be to world price shocks. Countries may attempt to reduce this vulnerability by investing in research and extension programs to increase domestic foodgrain production.[13]

B. Econometric Specifications

On the basis of the foregoing discussion we have developed investment equations for research expenditures and for extension expenditures to be estimated with two bodies of data. The first set of data is the commodity data for 26 countries and two time periods as presented in Appendix Table 4 and summarized in Tables 10 and 11. These data are suited to the estimation of the research investment function only. They are subject to "errors of attribution" to commodities, but since these errors are in the dependent variable, they may not be too serious from an econometric perspective. The commodity detail in the independent variables is important to our estimation. Our main set of data, for estimation of both aggregate research and extension investment functions, is the expenditure series reported in Appendix Tables 1 and 2. This data set encompasses 106 countries (grouped into several classes) for 8 three-year time periods (1959 through 1980).

Table 12 defines the variables actually used and presents means for the data sets employed. Independent variables are treated as exogenous variables in the analysis. In some cases they are lagged to reduce simultaneity biases.[14] In others they are expressed in ratio form to eliminate some errors of measurement. The model treats both research and extension spending decisions as jointly determined by the set of independent variables. The dependent variables could

Table 12: Variables Dictionary and Means: Investment Analysis

Variables	Commodities Data Base 26 Developing Countries*	General Data Base** Low-Income Developing Countries	Middle-Income Developing Countries	Semi-Industrialized Countries	Industrialized Countries	Planned Economies
Dependent						
Y_1: RESEXP (Expenditures in millions 1980$ on agricultural research)	.957	6.44	7.26	16.39	137.00	199.29
Y_2: EXTEXP (Expenditures in millions 1980$ on agricultural extension)	n.a.	8.42	10.60	15.16	59.76	76.83
Independent						
Economic-Political						
X_1: PROD (Value of production in millions 1980 dollars)	219.05	2486.08	1385.53	3071.86	11515.83	30192.04
X_2: XPORT (Value of exports in millions 1980 dollars)	23.52	396.82	567.68	980.20	4087.83	1558.14
X_3: MPORT (Value of imports in million 1980 dollars)	15.75	234.07	217.54	652.34	5380.66	2670.07
X_4: CROPSH (Share of crops in total agricultural product)	n.a.	.88	.84	.71	.43	.68
X_5: ARABLE (Ratio of arable land currently to arable land 6 years previous)	1.09	1.05	1.06	1.02	1.08	.996
X_6: REPRICE (Ratio Expenditures per SMY to expenditures per extension work, lagged one period)	9.86	16.87	7.69	6.18	3.85	2.37
Transfer-Related						
X_7: NATSR; (SMY's devoted to research in similar regions in other countries)	8.66+	5971.66	6082.86	7852.81	17873.43	20811.02
X_8: INTSR: (Expenditures in million 1980 $ by IARC's in similar regions)	n.a.	23.15	17.79	9.23	n.a.	n.a.
X_9: INTSP (Expenditures in million 1980 $ by IARC's in the commodity)	.953	n.a.	n.a.	n.a.	n.a.	n.a.
X_{10}: INTLOC (Dummy = 1 if IARC located in country)	.0183	.12	.1923	.0417	n.a.	n.a.
Political						
X_{11}: ECONAG (Percent of economically active labor force in agriculture)	54.45	81.40	60.12	36.09	13.66	42.26
X_{12}: URBANIZATION: (Percent of population living in urban areas)	35.72	9.43	29.84	50.53	65.39	40.24
X_{13}: INSTABILITY (Number of violent deaths per capita from political activity prior period)	.00003	.00006	.00001	.00001	negligible	.000006
X_{14}: FERTRICEPR: (Ratio of urea price to rice price, prior period)	2.73	n.a.	n.a.	n.a.	n.a.	n.a.

* means expressed on a per commodity basis.

** means expressed as country averages.

+Millions of 1980 dollars devoted to research in similar regions in other countries.

have been expressed in manpower quantity units, i.e., SMY's and Extension Workers, rather than in expenditure units. It was our judgment, however, that our expenditure measures were more reliable and less subject to definitional problems than were our manpower quantity units.

We have classified our independent variables as being economic-political, transfer-related and political in nature. The economic-political variables include the value of production, imports and exports. These variables are expected to be the basic determinants of research and extension spending. The share of crop products in total production is included in the general specification to control for different mechanisms of support for research and extension programs directed toward livestock and crop production. Our other two economic variables are ARABLE and REPRICE.

The variable ARABLE is defined as the ratio of arable land in the country to the arable land six years earlier. It is designed to be a proxy for the cost of land creation in the economy. The ratio will be high if it is inexpensive to create new arable land through clearing, drainage and irrigation, and low if arable land can be created only at high cost.

The variable REPRICE is defined as the ratio of expenditures per SMY to expenditures per extension worker, lagged one period. It is designed to be a proxy for the relative prices of research and extension workers facing the public sector. It is clearly not an ideal price since it includes expenditures for equipment, etc. Expressing it in ratio terms helps to correct for errors of measurement common to both research and extension spending and manpower as well as for currency exchange units. Lagging it allows us to argue that is pre-determined if not exogenous. Nonetheless, the reader should bear in mind that the variable probably has some error of measurement. We believe, however, that our earlier discussion shows this

variable to be essential to any analysis of relative investment in research and extension.[15]

We have also specified several transfer-related variables, designed to capture the possibilities for appropriating gains from research elsewhere. The NATSR variable measures the SMY's devoted to research in national programs in other countries in similar geo-climate regions (see Tables 7, 8 and 9 for definitions of regions and subregions). In this case, in spite of our judgment that SMY data have a higher degree of error than expenditure data, we believe the SMY data to be superior because they do not require exchange rate comparability.[16] The INTSR and INTSP variables, however, are defined in terms of expenditures because they do not have a problem of exchange rate conversion, since the budgets of the international centers are in dollars. We also felt that SMY data for the international centers are not readily comparable with the SMY data for national programs.[17]

Our political variables include a measure of the agricultural share of the labor force and an urbanization measure. These, of course, are not simply political variables. They have economic implications as well, but we believe that they are likely to measure primarily political factors, albeit rather imperfectly. The ECONAG variable is intended to measure the interests of agricultural laborers, while the urbanization variable is intended as a proxy for urban consumer interests. Our INSTABILITY variable is more clearly a political variable. We also define a price policy variable FERTRICEPR, the ratio of urea to rice prices, for our 26-country data base. This variable (again lagged) is designed to pick up responsiveness in research and extension investment to politically determined farm policies.

The functional form used in our analysis is indicated in Tables 13, 14, and 15. Variables shown in LN ( ) form are expressed in logarithmic form. Variables in ( ) ( ) form are interacted or multiplied. Since the commodity data for the 26 country sample differ in character from the country data, we did not impose the same specification on both. The CROPSH variable, for example, is intended as a control type variable only for the general country regressions reported in Tables 14 and 15. We also treated exports and imports differently in Table 13 because we had crop specific data. All specifications included country, commodity and year dummy variables where appropriate.

We expressed our dependent variable in terms of total spending on research or extension. Alternatively, we could have used an "intensity" specification in which we expressed the dependent variable as spending per unit of agricultural product. The specification used in this paper is more flexible in that it imposes a less stringent relationship between spending and product. It does not restrict scale relationships. We expect the elasticity of spending with respect to product to be less than one.

Research problems do not expand proportionately with size of the economy. The number of commodities produced and hence requiring specialized research attention may not be much higher for large countries than for small countries. In addition, the size of homogeneous geo-climate regions tends to be positively correlated with size of country, creating further economies of scale regarding the need to target research and extension programs to each region.

C. Results

Tables 13, 14 and 15 report regression estimates of the investment specification discussed above. Table 13 reports estimates of the research investment function based on the commodity data for 26 developing and

Table 13

Regression Estimates: Research Investment Function
(Commodity Data, 26 Countries)

Dependent Variable: LN(RESEXP)

Independent Variables	Cereal Grains	Staple Foods	Cash Crops	Tree Crops	Livestock	Pooled Data
LN(PROD) (α_1)	.354	.162	.119	.089	.083	.157
	(13.22)	(8.71)	(4.94)	(2.86)	(3.46)	(15.10)
LN(XPORT) (α_2)	.0164	.0953	.1314	.257	.148	.131
	(.45)	(2.78)	(3.99)	(6.32)	(3.93)	(8.43)
LN(MPORT) (α_3)	.00296	.1389	.014	.025	.0004	.032
	(.08)	(3.29)	(.45)	(.57)	(.01)	(1.90)
ARABLE (α_5)	-1.249	-.093	-.699	-1.597	-3.078	-1.419
	(1.27)	(.13)	(.82)	(1.94)	(3.77)	(3.70)
LN(REPRICE) (α_6)	.418	.295	.304	.483	.656	.455
	(2.78)	(2.79)	(2.42)	(3.95)	(5.46)	(8.04)
LN(NATSR) (α_7)	.0856	.0704	.1039	.080	-.051	.060
	(1.42)	(1.50)	(1.82)	(1.54)	(.95)	(2.55)
INTSP (α_9)	.147	-.346	na	na	.203	.189
	(.30)	(.42)			(2.91)	(2.83)
INTLOC (α_{10})	.323	1.571	na	na	-.266	.948
	(.65)	(4.34)			(.43)	(3.43)
(INTLOC)(YRSINT)	-.007	.060	na	na	.0016	-.007
	(.33)	(.76)			(.11)	(1.26)
ECONAG (α_{11})	-.0149	-.0171	-.031	.002	.041	-.007
	(.91)	(1.35)	(2.02)	(.12)	(2.93)	(1.01)
URBANIZATION (α_{12})	.0024	-.0036	-.0154	.004	.026	.0001
	(.16)	(.32)	(1.18)	(.29)	(2.12)	(.02)
INSTABILITY (α_{13})	-772.6	39.5	105.05	1443.5	246.2	201.9
	(.88)	(.06)	(.13)	(1.89)	(.33)	(.57)
FERTRICEPR (α_{14})	.056	-.030	-.037	-.050	-.147	-.045
	(.72)	(.57)	(.57)	(.78)	(2.24)	(1.51)
Asia Dummy	-.12	-.615	-.513	-.824	-1.41	-.76
Africa Dummy	.01	-.36	-.211	-.597	-1.54	-.66
R^2	.6834	.6209	.4512	.6068	.5659	.6403
F	16.00	18.96	9.65	21.51	12.53	49.43
Research Price Elasticity at mean	-.582	-.705	-.695	-.517	-.335	-.545
Production Elasticity at Mean	.356	.181	.123	.099	.086	.174

Notes: T ratios are in parentheses. Estimates of the intercepts with commodity dummies for the pooled samples are as follows. Cereal Grains: Wheat .0585, Corn -1.489, Rice -1.2259. Staple Foods: Groundnut -.759, Beans -.378, Cassava -.599, Sweet Potatoes -.655, Potatoes -.127, Cash Crops: Vegetables 1.78, Sugar -.465, Soy .467. Cotton -1.355. Tree Crops: Cocoa -.756, Coffee .018, Bananas -.060, Citrus .414, Coconut -.395. Livestock: Other Livestock .558, Cattle .556, Poultry -.592, Swine -.680.

Table 14

Regression Estimates Research Investment Function: Country Data
Dependent Variable LN(RESEXP)

Independent Variables	Low-Income Developing Countries	Middle-Income Developing Countries	Semi-Industrialized Countries	All Developing Countries	Industrialized Countries	Planned Economies
LN(PROD) (α_1)	.199 (.74)	-.565 (2.25)	-.532 (2.34)	-.099 (.78)	1.11 (3.27)	-2.07 (1.89)
(LN(PROD))(XPORT) (α_2)	.56E-04 (1.86)	.80E-05 (.50)	.65E-05 (1.28)	.36E-05 (.71)	-.956E-06 (1.27)	.104E-04 (.75)
(LN(PROD))(MPORT) (α_3)	.64E-04 (2.60)	-.31E-04 (1.26)	.41E-04 (4.25)	.29E-04 (3.39)	-.179E-05 (1.59)	-.642E-05 (2.07)
(LN(PROD))(CROPSH) (α_4)	.0603 (.29)	.174 (1.18)	-.013 (.13)	.038 (.48)	-.156 (2.88)	1.03 (2.67)
ARABLE (α_5)	-.954 (1.77)	-1.16 (2.87)	-.247 (.36)	-.629 (2.14)	-.218 (.48)	.72 (.18)
LN(REPRICE) (α_6)	.116 (1.24)	.336 (3.82)	-.006 (.09)	.158 (3.67)	.272 (4.92)	.74 (1.41)
LN(NATSR) (α_7)	-1.547 (2.84)	-.181 (.62)	-.162 (.60)	.289 (1.89)	.046 (.122)	-2.19 (2.13)
INTSR (α_8)	.0116 (2.53)	-.0072 (2.02)	.0076 (2.45)	-.002 (.78)	- -	- -
(INTSR)(INTLOC) (α_9)	.0083 (1.97)	-.0013 (.38)	.017 (1.78)	.0003 (.13)	- -	- -
(INTSR)(D5974)	.0060 (.78)	.0088 (2.02)	.0016 (.42)	.0012 (.44)	- -	- -
ECONAG (α_{11})	-.0348 (2.66)	-.0028 (.24)	-.015 (2.03)	-.010 (1.93)	-.0046 (.47)	-.012 (.43)
URBANIZATION (α_{12})	-.0241 (.61)	-.0034 (.24)	.021 (2.21)	.012 (2.26)	.011 (1.63)	-.027 (1.03)
INSTABILITY (α_{13})	-9.94 (.07)	2290.6 (1.24)	633.9 (.37)	13.3 (.09)	-416720.0 (1.22)	-2156.8 (2.23)
INTERCEPT	17.90	7.742	7.394	1.016	-5.726	39.47
Y_1 (year dummy)	-2.95	-2.64	-1.09	-.91	-1.09	-5.28
Y_2 (year dummy)	-2.15	-2.14	-.83	-.71	-.90	-4.01
Y_3 (year dummy)	-1.59	-1.74	-.55	-.52	-.62	-3.38
Y_4 (year dummy)	-1.01	-1.41	-.29	-.35	-.43	-2.51
Y_5 (year dummy)	-.82	-1.16	-.14	-.23	-.39	-1.59
Y_6 (year dummy)	-.71	-.93	-.16	-.24	-.25	-.93
Y_7 (year dummy)	-.16	-.12	-.06	-.03	-.21	-.38
R^2	.939	.951	.974	.948	.984	.976
F	44.11	63.64	117.9	93.30	195.25	46.95
Production Elasticity (computed at mean)	.289	-.423	-.508	-.054	1.029	-1.369
Price Elasticity (computed at mean)	-.884	-.664	-1.006	-.842	-.728	-.260

Table 15

Regression Estimates Extension Investment Function: Country Data
Dependent Variable LN(EXTEXP)

Independent Variables	Low-Income Developing Countries	Middle-Income Developing Countries	Semi-Industrialized Countries	All Developing Countries	Industrialized Countries	Planned Economies
LN(PROD) (α_1)	.036 (.16)	.224 (.95)	-.453 (1.52)	.146 (1.17)	.408 (1.16)	-1.97 (1.64)
(LN(PROD))(XPORT) (α_2)	-.212E-05 (.08)	.187E-04 (1.23)	.156E-04 (2.34)	.161E-04 (3.25)	.349E-06 (.45)	.207E-04 (1.35)
(LN(PROD))(MPORT) (α_3)	.494E-05 (.24)	-.125E-04 (.54)	.113E-04 (.89)	.361E-05 (.43)	.431E-06 (.37)	-.432E-05 (1.26)
(LN(PROD))(CROPSH) (α_4)	.142 (.82)	-.169 (1.22)	-.176 (1.33)	-.164 (2.14)	-.147 (2.62)	1.27 (3.00)
ARABLE (α_5)	-.792 (1.75)	-.524 (1.38)	.34 (.38)	-.318 (1.12)	-.800 (1.72)	.002 (.0005)
LN(REPRICE) (α_6)	-.213 (2.7)	.039 (.48)	-.242 (2.86)	-.140 (3.33)	-.154 (2.69)	.991 (1.72)
LN(NATSR) (α_7)	-.289 (.63)	.770 (2.81)	.092 (.26)	.406 (2.73)	-1.53 (3.89)	-1.016 (.89)
INTSR (α_8)	.0080 (2.08)	-.004 (1.08)	.007 (1.76)	-.0001 (.06)	- -	- -
(INTSR)(INTLOC) (α_{10})	.0079 (2.24)	-.00019 (.06)	.025 (2.02)	.0019 (.92)	- -	- -
(INTSR)(D5974)	.0075 (1.17)	.0049 (1.21)	-.0003 (.06)	.0022 (.87)	- -	- -
ECONAG (α_{11})	-.0005 (.04)	.016 (1.49	-.016 (1.63)	-.0037 (.71)	-.016 (1.57)	-.04 (1.38)
URBANIZATION (α_{12})	.0054 (.16)	.019 (1.47)	-.007 (.59)	.014 (2.66)	.012 (1.76)	-.075 (2.63)
INSTABILITY (α_{13})	-277.3 (2.35)	1655.6 (.95)	1638.8 (.72)	-238.7 (1.78)	777750.0 (2.20)	-588.0 (.55)
INTERCEPT	4.87	-6.09	6.83	-1.49	-16.36	27.57
Y_1 (year dummy)	-.74	-.19	-1.11	-.31	-2.15	-3.9
Y_2 (year dummy)	-.68	-.32	-.80	-.36	-1.54	-2.99
Y_3 (year dummy)	-.64	-.41	-.60	-.36	-1.04	-3.37
Y_4 (year dummy)	.15	.03	-.13	.14	-.59	-2.34
Y_5 (year dummy)	-.18	-.18	-.07	-.02	-.53	-1.21
Y_6 (year dummy)	-.04	-.17	-.08	-.002	-.33	-.73
Y_7 (year dummy)	-.07	.06	.09	.08	.01	-.33
R2	.954	.868	.952	.952	.978	.971
F	58.99	99.7	62.6	102.8	144.15	38.65
Price elasticities	-.787	-1.039	-.758	-.860	-.846	-1.991
Production elasticities	.161	.090	-.555	.044	.349	-1.085

semi-industrialized countries. Table 14 reports research investment function estimates based on the 106 country data set for several groups of countries, and Table 15 reports the comparable extension investment function estimates.

We will discuss our results in terms of the effects of each independent variable in order to stress the general findings better. The limitations of the data for the analysis have already been discussed. We do want to point out that a particular conclusion regarding the effect of an independent variable is strengthened or weakened according to the consistency of the estimates made in several different data sets.

1. Agricultural Product

Agricultural product should be an important determinant of both research and extension investment. As noted above we expect the elasticity of investment with respect to production to be less than one. In Table 13 we estimate this elasticity directly (our production data are by commodity). We find significant production impacts in all commodities for the 26 country data set. We also find these elasticities to be quite low reflecting what appear to be substantial scale economies to commodity specific research. A doubling of cereal grains production for example appears to induce only a 35 percent increase in research spending.

In Table 14 and 15, on the other hand, we opted for a slightly different formulation. Since we had data only for aggregate product and agricultural trade we felt that an interaction of the product and trade variables was desirable. Given the aggregate nature of the data, we chose this specification because trade effects were considered important because they affected the production elasticity.

Accordingly production elasticities are based on several terms. We have evaluated them at the means of each data set and reported them in the tables. For low-income developing countries and for all developing countries we obtain relatively low production elasticities. The middle-income developing countries

and the semi-industrialized countries are less consistent in their investment patterns. This is in contrast to the industrialized country data which show high production elasticities for research investment and medium elasticities for extension. We also found that the planned economies do not exhibit the expected production effects. However, as we will further note below, we were unable to show consistency in investment patterns for other variables for these economies as well.

2. Trade Effects

We expect that when commodities produced are exported, producer groups will have an increased incentive to engage in research. There are three reasons for this. First, because demand elasticities are higher for traded commodities, price effects from increased supply will be lower. Second, national governments may place a premium on export earnings. Third, the colonial legacy of a number of countries produced research on export commodities that may be reflected in the present data. This expectation is borne out strongly for the commodity data in the 26 country sample and,with somewhat less significance,for the developing countries in the country data. It was not borne out for the industrialized countries suggesting that producer groups may have less power and that governments are less concerned with trade issues.

Consistency would indicate that those countries responding to export patterns in research spending would also do so for extension. This is not consistently borne out by the data although all developing countries combined do appear to exhibit a strong export effect on extension spending.

We also expect import propensities to stimulate research and extension efforts for similar reasons. This may be particularly true in countries with a "low food price" policy in which food grains are imported to maintain low wage goods prices for urban populations. High import shares make these policies vulnerable to food aid policies and to price variability. The commodity data for the 26 countries

provides some support for this thesis for staple foods. It also receives support in the country data set for developing countries excluding the middle-income developing countries. We do not find large import effects on extension in these countries, however.

3. Crop Share in Output

The crop share variable was included because of the possibility that crop and livestock interest groups differed in their ability to generate support for research and extension. Our data show little effect of this variable on research spending in developing countries. However, for research spending in industrialized countries and for extension spending in developed and developing countries we obtain a negative effect. Apparently nonfield crop interest groups have more influence than do field crop interest groups in these countries.[18]

4. Land Expansion Effects

We expect a negative sign on the ARABLE variable which measures the ratio of arable land to arable land 6 years earlier. The lower this ratio, the higher the cost of obtaining growth via land expansion. This, in turn, is expected to induce investment in technology development activities. We obtain strong support for this proposition in our data. All ARABLE coefficients in our data sets except for those in the planned economies are negative. Most are significant. The effect is generally stronger for research than extension and is strongest for the low- and middle-income developing countries (see Table 14). Among commodities this effect appears to be weakest for research on staple foods and strongest for livestock research.

5. Price Effects

We have argued that countries appear to be allocating investment to research and extension in response to the real cost of resources. The variable REPRICE is a proxy for the relative prices of research and extension. In the form of these regressions the own price elasticity demand for research is

α_6-1[19], for extension it is $-\alpha_6-1$. Thus a coefficient of one for research or minus one for extension really shows no price effect. We find, however, that this variable is significantly different from one in all of the commodity regressions and in the country regressions for all developing countries and industrialized economies. The commodity regressions indicate a real elasticity of demand for research of about -.55. A 10 percent reduction in the price of research resources relative to the price of extension resources would lead to an increase in the quantity purchased of 5.5 percent (and a decrease in total spending on research of 4.5 percent). The country regressions show a larger response. In the developing countries, a ten percent decrease in research resource costs would lead to an increase of 8.4 percent in quantity of research purchased (and a decrease in research spending of 1.6 percent). The industrialized countries would respond with a 7.3 percent increase in quantities purchased.

6. Free Rider and Adaptive Effects

We have included several variables designed to determine whether countries respond to research investment either in other national research programs or in International Agricultural Research Centers. In the commodity data these include NATSR, national spending in other countries in the same geo-climate zone, INTSP, international spending on the commodity, INTLOC, a dummy variable indicating whether an international center (IARC) is located in the country and (INTLOC)(YRSINT), an interactive dummy variable designed to test whether the international location effect was related to the number of years of international spending in the commodity.[20] These variables have substantial policy implications because they represent basic externalities that might require international policy action.

Our commodity data show that "free-riding" may not be a serious problem. The positive effect of both neighboring research and international research in the pooled sample indicates that the adaptive response is outweighing the free rider effect in these countries. National programs appear to be responding

positively to an increase in research stocks providing them with adaptive research potential. This is particularly critical to IARC policy. Boyce and Evenson (1975) suggested that the IARC's had diverted funding from national programs. These data do not support that suggestion. It appears that both the levels of IARC spending and the location of an IARC in a country stimulate national spending.

The country data are somewhat less clear on this point. They suggest some net free-riding on other national research programs by low-income developing countries, but a net adaptive response for all developing countries. The IARC's appear to provide an adaptive stimulus only in the low-income developing countries. The interaction term, (INTSR)(INTLOC), produces similar results. The variable designed to test whether the IARC effect has changed over time INTSR(D5974) does not indicate a change except in the middle-income developing countries when the IARC effect was stronger in the 1959-74 period than in the more recent periods.

The extension data show roughly the same responses to these variables as is shown in the research data. They do not indicate that countries are attempting to free-ride on research by spending more on extension.

7. Political Factors

We have three political variables, ECONAG, a measure of the importance of the agricultural labor force, URBANIZATION, a measure of the importance of consumers, and INSTABILITY, a measure of political instability. We find a fairly consistent negative effect of the importance of the agricultural labor force. Actually this variable is probably a proxy for farm size, since we have production as a variable in the regression. Holding production constant, an increase in the proportion of the labor force in agriculture could be indexing farm size. Urbanization, on the other hand, appears to have a positive effect in both developing and industrialized countries in the country data set. This effect is somewhat

stronger for extension support than for research. Again this variable should be interpreted with caution. We are holding the proportion of the economically active labor force in agriculture constant, so urbanization in reflecting consumer interests. The results suggest that the general perspective that consumers do not support research or extension requires further study (Rose-Ackerman and Evenson, 1981).

Political instability appears to have little effect on research spending in developing countries but reduces research spending in the industrialized and planned economies. Extension spending appears to be reduced by instability in the developing countries and increased by instability in the developed countries.

All of the results discussed above, of course, are subject to the usual caveats applied to international comparisons. The planned economy group and the semi-industrialized economy groups exhibit the least consistency.

This is possibly explained by the fact that many semi-industrial economies are in periods of rapid transition and that planned economies have different mechanisms for support of public sector activities than market economies. In view of the nature of the data, however, we believe that the general interpretation offered here is justified.

III. Implications for Policy

The investment in IARC's and much of the investment in national research programs have been financed through international bilateral and multilateral aid. We do not have a good estimate of the magnitude of this aid but would judge that the majority of the capital budgets of research institutions in the past three decades have been aid financed.[21] This aid was generally forthcoming because donors believed that research and extension investment would produce low cost agricultural growth. They also recognized the difficulties associated with building research institutions, and to a lesser extent extension

programs, and provided technical assistance and visiting scientist services as part of their aid programs.

There is little doubt that the research capacity in terms of both numbers of SMY's and their levels of training and sophistication has made great progress since 1959. Nations appear to have turned consistently to research and extension investments as land conversion and land development became more costly. The high cost of research resources and the low cost of extension resources encouraged the stress on extension programs. A process of induced innovation, with a high degree of rational public sector investment behavior, was clearly at work.

Despite this progress, however, we would argue that the world continues to be far from optimal in its investment patterns and that significant institutional barriers remain to prevent many countries from moving to an optimal level, even if this optimum is narrowly defined in terms of an agricultural supply growth objective.

It is often said that poor countries cannot "afford" as much research as rich countries. This is only half true. Research and related extension programs are not consumer goods. They are investment goods which produce growth in agricultural product. That product is in turn just as valuable to a poor person or a poor country as to a rich person or a rich country. In fact it is probably more valuable. Poor countries, however, do have less purchasing power than rich ones in the market for scientific resources. Moreover, in the investment policies of poor countries, the poorest people -- whose elasticity of demand for food is highest -- seldom exert influence commensurate with their numbers.[22] Disparities in political power may thus reduce overall levels of investment in agricultural research, as well as affecting the type of research done, for example its allocation among commodities. The extremely low levels of research investment in such staple crops as cassava and

sweet potatoes can be understood in this light.

Public good problems, arising from the spillover of research benefits to similar geo-climate regions in other countries, also reduce international investment below optimal levels. Our analysis found evidence of "free-riding" -- in the sense of a country investing less when its neighbors invest more -- only in the case of the low-income developing countries. But the fact that a government can appropriate only part of the benefits of its research expenditures undoubtedly depresses international investment levels. To some extent this is offset by the fact that investment in adaptive research increases the capability to benefit from the research of ecological neighbors, but the impact of this offsetting effect is inherently limited: if everyone concentrated on adaptive research, there would soon be nothing left to adapt.

If the real cost of research and extension personnel relative to the value of agricultural product is lower in poor countries than in rich ones, then, all other things equal, the poor country would invest so as to produce more SMY's and extension workers per unit product than the rich country. We have seen that poor countries do in fact have much higher extension workers to product ratios than rich countries. This is not only because extension workers are less expensive to produce than research scientists, but also because they are less mobile. The world market for extension workers is quite strongly segmented along national lines.

If the institutional barriers to achieving low cost SMY's could be overcome we would expect to observe poor countries also having higher SMY to product ratios. The production of technology is ultimately a time-intensive activity and countries with less expensive time have a comparative advantage in its production. The basic factor preventing developing countries from realizing low-cost SMY's and building more effective research institutions is their limited capacity to produce scientists at home. A second, related factor is

the distorted price system applied to scientific resources. In many countries today a two tier system of scientific manpower exists. The first consists of home-trained scientists trained to the Bachelors, Masters and, in some cases, Ph.D. levels. The second tier consists of those who have been sent abroad for scientific training and have returned. Agricultural research systems continually lose many of the best scientists from both tiers to the private sector, which pays higher salaries, usually for non-research jobs. Many of the best products of the system are also lost through "brain-drain", often, somewhat ironically, to international agencies.

As a result we find only a few developing countries able to achieve low-cost SMY's. India, because of its size and the massive aid granted in the form of student fellowships in earlier years, has been able to realize relatively low-cost SMY's and has built a large and effective research system. But in recent years India too has lost top agricultural scientists to other countries. Many other countries are in an unstable equilibrium in which research institutions are continually being raided and replacement of departing scientists is very costly.

Our study indicates that countries will respond to lower prices of national scientific resources. It would appear to us that after two decades or so in which major attention has been given to building IARC's, the issue of training scientists at low cost in national programs now deserves much greater attention from aid donors. The development of a capacity to train scientists is fortunately highly complementary with the conduct of research. Graduate programs of quality must be research based. Aid programs to support graduate programs in agricultural sciences would not eliminate all the institutional barriers to optimal research investment levels, but they could ease a major one.

In the meantime national governments will have to consider

carefully the consequences of current pricing policy. If Ph.D. scientists are paid far less than competitive wages for agricultural research, then they will leave for the private sector or go abroad. Our data show that national governments are moving to build research programs. Much of this expansion has been in terms of quantity of resources employed. Quality of resources has probably lagged behind, and until it catches up, the potential of the new institutions will not be fully realized.

FOOTNOTES

1. See Kislev and Evenson (1975) and Evenson, Waggoner and Ruttan (1980) for a review of this evidence.

2. See Oram and Bindlish (1981).

3. We did have enough data to justify extending the constructed time series to 1980 for the countries of Latin America, North America/Oceania, and Western Europe. The extended times series are presented in Appendix Table 2. For Asia, Africa, and Eastern Europe/USSR, the data in Table 2 are taken directly from Boyce and Evenson.

4. It should be noted, however, that our data for China are subject to a relatively high degree of uncertainty owing to the paucity of source material. Hence the percentage shares in Table 3 are calculated both with and without China.

5. Problems of definitional consistency in enumerating scientists may, however, account for part of the difference.

6. This point raises another problem which we encountered in compiling the data for this paper, that of distinguishing between capital and operating expenditures. Most of our data sources did not allow us to break expenditures into these two categories. Rapid periods of growth in national program expenditures often reflect increased capital spending which occurs when a country engages in program-building. Program-building activities are usually funded by outside sources and probably explain the dramatic increases in expenditures in Indonesia and Pakistan between 1974 and 1977. In both countries, 1980 expenditures had decreased from the 1977 high. While these program-building expenditures may be used in part to increase the numbers of scientists, they are more often used to improve laboratory facilities or raise salary levels of present research personnel. It is, therefore, not surprising that SMY's often increase at a slower rate than expenditures.

7. The five country groups are: 1) Industrialized Countries -- members of the Organization for Economic Cooperation and Development, except for Greece, Portugal, Spain and Turkey; 2) Planned Economies -- Eastern Europe, USSR and China; 3) Semi-industrialized countries -- other countries with annual per capita income above $1050; 4) Middle-income developing countries -- other countries with annual per capita income between $360 and $1050; 5) Low-income developing countries -- other countries with annual per capita income below $360. See World Bank, World Development Report, 1980, p. viii. We use the term "developing countries" to refer to the latter three groups collectively.

8. The first study to incorporate geo-climate data to analyze transferability of technology was an international analysis of wheat and maize productivity by Evenson and Kislev (1973). See also Boyce and Evenson (1975), pp. 108-115.

9. We checked these against U.S. data as well and found close agreement.

10. Groundnuts, cassava and coconuts are export crops in some countries as well.

11. In terms of SMY's the IARC's represent only 2 percent of the scientific manpower directed toward agricultural supply improvement in the developing and semi-industrialized countries.

12. See, for example, Otsuka (1979), Huffman and Miranowski (1981), and Rose-Ackerman and Evenson (1982).

13. It is true that if urban consumer interests are important, they cannot be served as well by cost reductions in traded commodities as by cost reductions in non-traded commodities.

14. Technically we are viewing some of these variables as predetermined and the model as a recursive model.

15. The standard "errors in variables" analysis suggests that the coefficient on this variable will be biased toward zero.

16. In the 26-country data set, however, we did not attempt to allocate SMY's by commodity. The NATSR variable in this data base, therefore, is a measure of expenditures devoted to research in national programs in other countries in similar regions.

17. This is related to the extensive use of junior scientists, post-doctoral fellows, trainees and the like in IARC's. Many junior scientists and technicians in the IARC's would be considered scientists in most national programs.

18. This may be due to the fact that demand elasticities for animal products may be higher than for crop products in developing countries.

19. Note that

$$d(PQ) = dP(Q) + dQ(P)$$

$$d\frac{(PQ)}{dP} = Q + \frac{dQ}{dP}(P)$$

$$d\frac{(PQ)}{dP}\frac{P}{PQ} = \frac{QP}{PQ} + \frac{dQ}{dP} = 1 + \eta$$

20. The values for the YRSINT variable for the 1972-75 and 1976-79 periods were 1 and 5 for groundnuts and potatoes, 4 and 8 for beans and beef, 7 and 11 for cassava, 12 and 16 for rice, 17 and 21 for maize, and 24 and 28 for wheat.

21. Ahsan (1981) states that the majority of external assistance for Bangladesh has been used for capital investment rather than for supplementation of operating budgets and suggests that donors might receive greater returns to their capital investments if they would also supplement operating budgets. This external assistance has accounted for 30-40 percent of Bangladesh's agricultural research expenditures during the 1970s and, therefore, must have a substantial impact on the direction of the country's programs. We have no reason to believe that Bangladesh differs from other developing countries in this respect.

22. As Ruttan (1978) has observed, "The relative power of different economic and social groups over the politico-bureaucratic structure is the primary determinant in getting their specific demands eventually translated into a supply of new knowledge or new technology."

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Appendix Table 1: Agricultural Research Expenditures and Manpower in Western Europe (A Constructed Time Series, 1959 - 1980)

	Expenditures (000 Constant 1980 US $)								Manpower (SMY's)							
Country	1959	1962	1963	1968	1971	1974	1977	1980	1959	1962	1965	1968	1971	1974	1977	1980
Denmark	4,797	9,310	15,504	26,741	24,889	24,835	28,308	32,267	170	200	300	500	530	560	638	727
Finland	3,949	5,360	6,976	8,089	8,664	11,080	14,935	17,803	136	152	165	180	215	242	326	389
Iceland	493	559	960	754	1,064	1,298	1,583	1,422	22	20	19	19	27	35	44	47
Ireland	3,949	11,284	16,612	19,047	24,654	26,171	25,956	44,824	130	250	310	350	422	490	486	300
Norway	12,696	11,989	17,262	19,829	22,776	26,744	32,122	37,511	260	280	300	308	393	480	577	674
Sweden	6,769	14,104	20,763	26,091	29,350	28,655	34,180	40,205	100	120	170	205	250	300	359	422
U.K.	62,065	70,527	78,902	106,973	141,350	152,827	166,005	235,495	1,000	1,300	1,850	2,578	2,840	3,310	5,551	5,468
Northern Europe	94,718	123,134	156,980	207,523	252,747	271,610	303,089	409,527	1,818	2,322	3,114	4,140	4,677	5,417	7,981	8,027
Austria	3,949	3,949	5,814	8,349	10,331	8,979	10,978	13,415	80	90	100	105	110	110	134	164
Belgium	12,696	14,104	14,866	18,552	19,488	29,228	30,599	35,709	260	550	650	650	650	800	838	978
France	22,569	49,369	96,897	203,511	187,840	201,541	179,770	221,590	440	720	850	1,086	1,130	1,240	1,868	2,191
Germany	59,242	141,056	193,797	234,819	234,800	229,240	242,763	252,044	1,300	1,700	2,100	2,500	2,750	3,000	3,177	3,298
Netherlands	36,659	56,422	76,688	70,445	79,832	106,980	220,106	277,762	638	720	820	900	981	1,100	1,538	1,724
Switzerland	5,924	8,180	10,796	23,482	35,220	48,714	55,892	70,713	170	210	250	285	295	325	373	472
Central Europe	141,054	273,082	398,859	559,157	567,511	624,682	740,108	871,233	2,888	3,990	4,770	5,526	5,916	6,575	7,928	8,827
Greece	7,899	7,927	9,413	8,871	9,392	9,362	11,809	12,683	195	212	280	280	325	390	492	528
Italy	22,569	28,211	33,222	46,965	76,310	84,054	59,668	106,988	600	900	1,091	1,025	1,099	1,200	1,218	636
Portugal	4,231	7,053	8,305	11,740	18,784	19,103	19,427	19,757	300	300	350	400	450	500	372	378
Spain	4,513	9,310	13,841	31,308	46,960	53,490	60,928	69,400	450	550	580	615	640	670	1,004	1,144
Southern Europe	39,212	52,501	64,781	98,884	151,446	166,009	151,832	208,828	1,545	1,962	2,301	2,320	2,514	2,760	3,086	2,686
Regional Total	274,984	448,717	620,621	865,564	971,704	1,062,301	1,195,029	1,489,588	6,251	8,274	10,185	11,986	13,107	14,752	18,995	19,540

Appendix Table 1: Agricultural Research Expenditures and Manpower in Eastern Europe & USSR
(A Constructed Time Series, 1959 - 1980)

	Expenditures (000 Constant 1980 US$)													
Country	1959	1962	1965	1968	1971	1974	1977-80	1959	1962	1965	1968	1971	1974	1977-80
Bulgaria	11,284	13,823	15,781	27,657	37,568	38,019	38,264	250	300	350	650	981	960	966
Czechoslovakia	101,560	115,242	122,645	130,194	129,140	143,115	162,458	1,470	1,770	2,070	4,015	3,150	4,100	4,654
Hungary	5,642	7,335	33,222	67,836	61,048	69,050	67,737	400	500	1,500	1,560	1,420	1,500	1,471
Poland	22,569	39,496	57,308	69,923	77,484	93,263	95,233	1,240	2,170	3,210	4,100	4,700	5,150	5,259
Romania	19,747	33,853	49,834	61,053	68,092	82,560	95,398	650	850	1,285	1,900	2,500	3,200	3,698
Yugoslavia	14,104	14,248	14,396	20,611	28,176	34,386	35,017	1,080	1,100	1,140	1,720	1,890	1,970	2,006
Eastern Europe[1/]	195,896	250,877	328,368	422,546	449,642	508,032	553,400	5,701	7,493	10,702	15,618	16,400	18,906	20,220
USSR	372,388	688,354	744,595	781,682	910,554	997,900	939,383	12,000	20,400	24,450	25,600	29,800	33,350	31,394
Regional Total	568,284	939,231	1,072,963	1,204,228	1,360,196	1,505,932	1,492,783	17,701	27,893	35,152	41,218	46,200	52,256	51,614

1/ Includes adjustment for missing countries based on estimates (% oc subtotals):

D.D.R.	11%
Albania	1%
	12%

Appendix Table 1: Agricultural Research Expenditures and Manpower in North America and Oceania (A Constructed Time Series, 1959 - 1980)

	Expenditures (000 Constant 1980 US$)								Manpower (SMY's)							
Country	1959	1962	1965	1968	1971	1974	1977	1980	1959	1962	1965	1968	1971	1974	1977	1980
Australia	76,169	95,918	156,421	169,591	281,760	267,447	286,823	306,199	1,500	1,700	1,900	2,130	3,000	3,200	2,425	2,589
New Zealand	14,952	16,927	27,131	29,484	44,612	68,773	73,713	78,683	250	250	450	475	590	700	707	713
Oceania[1/]	91,577	113,408	186,553	200,071	328,004	337,901	362,339	386,806	1,759	1,960	2,362	2,618	3,608	3,919	3,132	3,302
Canada	104,664	108,614	129,013	211,336	234,800	229,240	277,925	241,246	950	1,050	1,150	1,300	1,450	1,520	1,820	1,836
United States	564,224	648,858	808,409	939,275	1,056,600	1,050,683	1,072,880	1,094,338	5,740	6,150	6,570	7,000	7,400	7,500	8,303	8,469
North America	668,889	757,472	937,423	1,150,612	1,291,400	1,279,923	1,350,805	1,335,584	6,690	7,200	7,720	8,300	8,850	9,020	10,123	10,305
Regional Total	760,466	870,880	1,120,976	1,350,652	1,619,404	1,617,824	1,713,144	1,722,390	8,449	9,160	10,082	10,918	12,458	12,939	13,255	13,607

1/ Includes adjustment for missing countries based on estimates: 0.5% of subtotals

Appendix Table 1: Agricultural Research Expenditures and Manpower in Latin America (A Constructed Time Series, 1959 - 1980)

	Expenditures (000 constant 1980 US$)								Manpower (SMY's)							
Country	1959	1962	1965	1968	1971	1974	1977	1980	1959	1962	1965	1968	1971	1974	1977	1980
Argentina	28,211	32,442	48,991	41,968	42,978	70,441	53,490	59,750	320	420	670	7650	880	880	890	1,065
Chile	1,693	2,963	6,229	6,915	16,436	10,315	11,960	11,319	32	58	113	162	171	192	171	177
Paraguay	423	564	554	730	775	1,146	2,529	5,357	5	10	15	20	26	31	48	63
Uruguay	761	1,411	1,385	2,087	2,348	3,437	3,399	3,821	7	35	35	60	75	100	180	222
Temperate South America	31,088	37,380	57,159	51,700	62,537	85,339	71,378	80,247	364	523	833	892	1,152	1,203	1,289	1,527
Bolivia	507	669	693	653	587	427	6,459	11,374	20	29	40	50	60	86	86	125
Brazil	11,284	22,569	41,527	60,008	70,440	114,620	130,735	174,012	200	400	800	1,350	1,650	2,000	3,121	2,935
Colombia	14,104	13,428	17,746	25,464	30,806	31,329	29,668	32,231	200	338	300	550	809	870	824	881
Ecuador	704	1,411	2,768	4,226	5,260	8,901	8,132	6,100	12	20	34	64	94	200	183	208
Guyana	348	519	814	1,198	1,380	1,851	1,601	2,678	6	10	15	23	29	36	27	41
Peru	1,073	2,104	4,154	8,479	11,740	12,895	6,871	8,163	32	65	131	155	180	220	295	290
Venezuela	6,772	11,193	13,677	19,829	17,845	15,283	34,509	34,885	100	176	184	155	226	354	329	360
Tropical South America	34,792	51,893	81,379	119,857	138,058	185,306	217,975	269,443	570	1,038	1,504	2,347	3,048	3,766	4,865	4,840
Barbados	172	103	244	295	449	593	514	652	3	4	5	7	8	10	13	23
Costa Rica	775	930	1,108	1,043	2,747	2,374	1,935	2,168	40	48	59	55	61	71	60	75
El Salvador	1,186	1,186	1,108	1,174	1,409	1,815	2,507	2,391	50	50	48	60	83	85	78	78
Guatemala	862	1,025	1,218	1,474	2,247	2,963	4,083	5,332	19	22	27	43	47	58	71	123
Haiti	86	103	122	147	225	296	356	452	8	9	11	18	20	24	33	37
Honduras	1,129	1,411	1,660	1,827	1,878	1,719	831	1,047	35	43	51	60	67	72	66	60
Jamaica	172	205	244	295	1,132	1,810	1,639	935	15	17	20	32	55	88	85	40
Mexico	5,079	5,924	6,922	8,871	14,558	22,924	20,393	70,929	190	220	280	520	540	711	1,074	1,079
Nicaragua	451	803	1,385	1,827	1,878	1,719	1,711	2,211	8	10	17	22	29	34	44	57
Panama	345	410	487	589	899	1,185	1,515	2,482	11	13	16	25	44	49	29	51
Trinidad & Tobago	172	205	244	295	449	593	832	709	10	11	14	22	23	29	39	40
Dominican Rep.	690	820	975	1,179	1,798	2,370	3,486	2,514	10	11	14	22	23	29	40	40
Caribbean & Central America[1/]	13,676	16,144	19,332	23,390	36,493	49,644	48,956	112,941	491	564	691	1,090	1,230	1,552	2,015	2,167
Regional Total	79,556	105,417	157,860	194,947	237,088	320,289	338,309	462,631	1,425	2,125	3,028	4,329	5,430	6,521	8,169	8,534

1/ Includes adjustment for missing countries based on estimates (1% of subtotals):

CATIE (IICA)	4
Cuba	19
	23

ppendix Table 1: Agricultural Research Expenditures and Manpower in Africa
(A Constructed Time Series, 1959 - 1980)

	Expenditures (000 Constant 1980 US$)								Manpower (SMY's)							
ountry	1959	1962	1965	1968	1971	1974	1977	1980	1959	1962	1965	1968	1971	1974	1977	1980
orocco	2,116	3,386	4,154	5,217	6,574	6,112	8,633	8,026	17	25	34	43	60	65	543	686
udan	2,820	4,513	6,922	7,828	9,580	8,213	11,388	13,600	50	50	50	55	128	140	144	150
gypt	11,284	16,363	21,040	24,785	24,067	21,015	22,325	23,717	400	500	600	700	750	800	850	903
unisia	1,204	1,800	2,383	2,807	2,428	3,874	5,320	6,764	35	44	53	62	72	140	212	285
ibya	973	1,456	1,927	2,270	2,413	2,125	2,541	2,793	39	58	77	91	97	80	112	123
orth Africa[1/]	20,789	31,095	41,161	48,485	50,920	46,713	56,734	62,037	590	738	887	1,037	1,207	1,335	2,028	2,340
ameroon	564	1,129	1,684	2,374	3,052	3,437	3,364	3,788	10	15	20	48	72	96	94	106
had	282	564	831	1,043	1,174	1,146	1,369	1,602	7	10	16	23	26	30	36	42
ahomey	564	1,129	1,799	1,956	2,043	1,719	2,053	2,403	7	10	13	15	16	16	16	19
ambia	23	28	42	47	52	47	56	66	5	5	6	6	5	5	6	7
abon	68	80	89	124	141	239	285	334	4	4	6	5	5	5	6	6
hana	3,386	4,513	5,537	6,262	6,574	5,731	12,443	12,655	60	80	100	120	140	304	301	352
vory Coast	5,642.	8,462	11,073	13,045	14,088	12,036	12,399	12,771	40	60	80	100	110	110	113	116
iberia	94	94	141	211	282	282	360	394	14	16	25	18	14	16	18	20
ali	845	1,411	1,738	2,869	3,992	4,393	5,246	6,141	12	15	21	16	25	35	47	68
auritania	115	151	207	223	259	258	402	284	3	4	6	6	7	7	11	8
igeria	14,104	22,569	33,222	31,308	37,568	38,207	147,429	121,840	110	170	170	195	300	300	843	1,084
enegal	3,668	4,513	4,982	6,001	6,574	7,640	8,369	9,726	45	55	55	85	130	160	148	172
ierra Leone	282	394	444	470	564	573	687	698	16	22	28	23	30	36	34	35
pper Volta	451	507	636	730	740	669	1,087	1,105	5	6	7	10	10	11	12	12
aire	8,462	4,797	6,922	7,828	8,230	8,608	5,949	5,095	20	25	35	30	66	85	113	97
est Africa[2/]	44,333	57,892	79,750	85,664	98,133	97,733	231,723	205,737	412	572	676	805	1,099	1,398	2,068	2,466

Appendix Table 1: Agricultural Research Expenditures and Manpower in Africa (continued)

	Expenditures (000 Constant 1980 US$)								Manpower (SMY's)							
Country	1959	1962	1965	1968	1971	1974	1977	1980	1959	1962	1965	1968	1971	1974	1977	1980
Burundi	282	423	721	1,043	1,017	958	3,332	3,608	10	13	16	20	24	27	22	41
Ethiopia	845	1,411	2,214	3,372	3,412	3,437	3,370	3,400	8	12	25	30	52	65	110	155
Kenya	1,411	1,975	3,322	5,480	7,748	13,492	19,844	22,712	25	40	70	140	210	280	299	400
Madagascar	2,256	5,079	6,091	6,915	6,409	6,125	5,309	4,878	25	40	50	65	70	80	76	68
Malawi	704	1,129	1,660	2,087	2,818	3,437	4,641	5,660	15	22	35	44	57	208	242	276
Mauritius	1,411	2,116	2,768	4,567	5,870	6,208	7,450	7,879	25	30	35	41	51	61	46	50
Rwanda	564	648	664	653	859	763	894	945	9	10	8	8	16	18	23	24
Tanzania	1,552	2,116	2,768	5,480	7,748	9,933	7,436	7,214	45	60	65	60	100	145	194	212
Uganda	1,411	2,116	3,322	5,480	7,748	6,687	5,804	7,452	20	32	40	52	80	80	135	175
Zambia	1,252	2,042	2,824	4,209	7,394	7,176	5,575	5,202	21	31	41	55	81	79	104	96
East Africa[3/]	12,740	20,770	28,726	42,822	55,615	63,455	69,384	75,156	221	316	420	561	808	1,137	1,364	1,632
Botswana	42	141	444	521	775	629	2,803	4,977	1	2	2	10	33	30	46	61
Lesotho	28	70	110	209	303	324	429	465	1	2	3	3	7	10	13	14
Zimbabwe	1,411	1,411	2,076	3,783	5,119	7,640	7,467	10,560	140	100	134	135	172	180	155	201
South Africa	39,496	56,422	77,519	62,619	46,960	47,758	63,441	64,519	550	720	900	900	900	1,000	1,328	1,351
Swaziland	310	437	512	521	695	669	1,357	1,306	4	6	9	11	12	12	24	23
South Africa	41,287	58,482	80,661	67,653	53,852	57,020	75,497	81,827	696	830	1,049	1,059	1,124	1,232	1,566	1,650
Regional Total	119,149	168,239	230,298	244,624	258,520	264,921	433,338	424,757	1,919	2,456	3,032	3,462	4,236	5,102	7,026	8,088

Notes: 1/ North Africa totals adjusted for missing countries (% of subtotals):

	Expenditures	Manpower
Algeria	13	9

2/ West Africa totals adjusted for missing countries (% of subtotals):

Angola	4
CAR	2
Congo	3
Guinea	2
Niger	2
Benin	1
Guinea-Bissau	1
	15

3/ East Africa totals adjusted for missing countries (% of subtotals):

Mozambique	7
Somalia	2
	9

Appendix Table 1: Agricultural Research Expenditures and Manpower in Asia
(A Constructed Time Series, 1959-1980)

	Expenditures (000 constant 1980 US$)								Manpower (SMYs)							
Country	1959	1962	1965	1968	1971	1974	1977	1980	1959	1962	1965	1968	1971	1974	1977	1980
Cyprus	423	704	831	1,005	915	944	1,599	2,410	15	18	20	24	37	54	56	58
Iran	4,231	7,448	12,458	16,699	23,480	34,386	39,840	45,163	55	110	250	360	550	580	457	518
Israel	11,566	14,104	16,335	19,568	18,314	22,578	25,558	30,209	170	220	270	327	440	500	566	630
Jordan	128	175	243	339	427	852	869	849	6	8	14	17	23	40	38	35
Turkey	4,797	6,206	9,690	16,960	21,367	22,924	24,640	26,463	150	200	397	440	485	540	580	623
Syria	282	704	1,219	2,219	2,700	3,057	4,045	4,963	5	10	15	40	75	110	145	179
West Africa[1/]	24,427	33,449	46,485	64,741	76,611	96,605	110,068	125,465	457	645	1,101	1,377	1,835	2,079	2,100	2,329
Bangladesh	-	-	-	-	2,348	2,677	15,735	27,613	-	-	-	-	150	190	1,234	1,320
Sri Lanka	3,104	3,940	4,982	6,286	6,340	5,731	4,244	5,057	50	65	80	95	105	130	287	422
Nepal	906	1,109	1,337	1,519	2,163	2,229	2,556	2,634	71	87	104	119	169	184	220	226
India	24,825	29,622	41,020	45,717	66,108	66,868	103,855	120,167	1,150	1,160	1,450	1,800	1,950	2,150	2,244	2,345
Pakistan	2,256	3,386	4,982	5,741	4,696	4,776	38,528	29,899	120	180	270	350	250	280	1,560	1,212
South Asia[2/]	32,024	39,199	53,891	61,041	84,105	84,749	169,866	190,931	1,433	1,537	1,961	2,435	2,703	3,022	5,711	5,691
Indonesia	564	2,256	4,705	6,783	8,688	8,023	42,229	33,200	15	70	140	240	340	592	914	1,473
Malaysia	3,386	5,924	9,136	9,653	11,740	11,463	19,564	30,391	40	90	150	156	195	149	284	386
Philippines	2,781	3,633	4,255	4,877	5,499	6,844	8,637	9,533	200	300	400	500	600	620	630	640
Thailand	1,552	4,231	7,476	9,652	11,740	11,463	23,547	21,600	150	250	350	475	600	725	1,134	1,264
Southeast Asia[3/]	9,028	17,488	27,873	33,752	41,057	41,194	102,435	103,249	441	774	1,135	1,494	1,891	2,274	3,229	4,102
China	54,166	169,265	332,223	469,638	535,344	623,434	633,420	643,555	1,250	4,000	8,000	11,000	13,500	16,000	17,000	17,272
Hong Kong	141	183	195	195	200	190	118	132	9	8	8	8	10	12	8	8
Japan	135,414	197,479	334,992	420,064	575,260	611,306	645,543	684,276	7,200	8,500	10,000	11,500	13,700	14,000	14,784	15,671
South Korea	2,538	2,820	3,322	4,567	23,381	24,400	26,607	29,012	300	320	340	450	744	807	880	960
Taiwan	1,975	3,245	3,877	4,539	5,400	5,539	12,520	14,000	250	275	310	350	375	400	404	452
East Asia[4/]	141,469	205,765	345,809	433,659	610,283	647,849	691,636	734,694	7,837	9,194	10,765	12,431	15,008	15,371	16,237	17,262
Regional Total	261,114	465,166	806,281	1,062,831	1,347,400	1,493,831	1,707,425	1,797,894	11,418	16,150	22,962	28,737	34,937	38,746	44,277	46,656

Notes:

1/ West Asia totals adjusted for missing countries based on estimates (% of subtotals):

Iraq	2
Lebanon	6
Others	6
	14

2/ South Asia totals adjusted for missing countries based on estimates (% of subtotals):

Afghanistan	2
Others	1
	3

3/ Southeast Asia totals adjusted for missing countries based on estimate (5% of subtotals). Missing countries: Burma, Cambodia, Laos, Portuguese Timor, Singapore, Vietnam.

Appendix Table 2: Agricultural Extension Expenditures and Manpower in Western Europe (A Constructed Time Series, 1959-1980)

	Expenditures (000 Constant 1980 US$)							Manpower (workers)							
Country	1959	1962	1965	1968	1971	1974	Average 1977-80	1959	1962	1965	1968	1971	1974	1977	1980
Denmark	15,516	16,927	17,995	20,873	21,132	19,103	22,340	742	788	790	945	947	949	951	954
Finland	12,414	16,081	20,460	18,786	18,784	24,835	26,720	670	750	861	825	750	743	685	634
Iceland	704	845	970	939	939	956	1,192	42	41	42	42	43	44	47	51
Ireland	5,079	6,488	8,305	9,392	13,384	14,137	17,309	345	385	436	465	504	540	551	578
Norway	11,848	12,977	13,841	14,351	12,679	10,125	15,047	666	678	650	645	640	640	815	989
Sweden	13,823	14,952	15,781	15,915	15,262	13,182	16,584	740	800	844	852	817	705	760	815
U.K.	53,600	67,707	80,288	99,147	112,704	93,603	114,886	1,588	1,693	1,650	1,700	2,100	2,300	2,419	2,554
Northern Europe	112,983	135,977	157,640	179,403	194,884	175,943	213,078	4,793	5,130	5,273	5,474	5,801	5,921	6,228	6,575
Austria	11,284	14,104	16,612	18,260	18,784	17,192	22,619	726	700	700	680	650	620	699	777
Belgium	1,242	1,552	1,827	2,010	2,066	1,911	2,773	345	398	340	284	280	275	342	409
France	23,132	28,702	83,056	75,664	65,744	70,874	139,796	2,460	3,668	4,400	5,200	5,700	6,300	6,530	6,790
Germany	49,369	57,834	63,675	62,098	61,048	53,490	57,698	2,936	4,400	4,400	4,500	4,812	5,100	4,714	4,874
Netherlands	15,234	23,980	31,839	37,821	41,090	39,352	27,800	1,228	1,598	1,500	1,500	1,500	1,250	1,446	1,471
Switzerland	2,820	3,808	4,705	6,391	7,396	7,640	9,336	170	270	370	480	505	530	555	582
Central Europe	103,082	146,417	201,714	202,254	196,128	190,460	260,022	7,865	11,034	11,710	12,644	13,447	14,075	14,286	14,903
Greece	3,668	4,034	4,318	4,226	3,569	3,344	3,933	330	440	400	480	839	900	907	913
Italy	11,284	19,747	29,071	37,831	37,568	33,431	42,046	2,000	2,500	2,500	3,050	3,250	3,500	3,772	4,042
Portugal	845	5,642	10,244	10,697	10,566	9,552	12,009	500	650	692	850	970	1,100	1,185	1,270
Spain	2,153	8,462	13,841	18,263	19,958	18,148	23,932	500	500	700	920	1,050	1,200	1,356	1,512
Southern Europe	17,950	37,885	57,474	71,018	71,661	64,474	81,920	3,330	3,590	4,292	5,300	6,109	6,700	7,220	7,737
Regional Total	234,016	320,279	416,829	452,676	462,673	430,877	556,020	15,988	19,759	21,275	23,418	25,357	26,696	27,734	29,215

Appendix Table 2: Agricultural Extension Expenditures and Manpower in North America and Oceania (A Constructed Time Series, 1959-1980

	Expenditures (000 Constant 1980 US$)							Manpower (workers)						
	1959	1962	1965	1968	1971	1974	Average 1977-80	1959	1962	1965	1968	1971	1974	1977-80
Country														
Australia	30,576	50,780	55,371	62,619	93,920	95,517	113,478	1,700	1,750	1,800	2,000	2,250	2,300	2,400
New Zealand	7,899	8,462	9,136	10,958	11,740	16,239	19,296	370	375	375	400	450	450	300
Oceania[1/]	50,466	59,538	64,828	73,946	106,188	112,314	132,774	2,080	2,136	2,186	2,412	2,713	2,764	2,714
Canada	50,780	56,422	69,212	78,273	84,528	85,965	102,140	1,500	1,500	1,750	2,000	2,100	2,200	2,200
U.S.	282,112	310,323	332,223	391,365	469,600	477,583	567,388	10,000	10,000	10,200	10,400	10,600	10,800	9,653
North America	332,892	366,746	401,435	469,638	554,128	563,548	669,528	11,500	11,500	11,950	12,400	12,700	13,000	11,853
Regional Total	383,358	426,284	466,263	543,583	660,316	675,862	802,302	13,580	13,636	14,136	14,812	15,413	15,764	14,567

1/ Totals adjusted for missing countries based on estimates of 0.5% of subtotals.

Appendix Table 2: Agricultural Extension Expenditures and Manpower in Latin America (A Constructed Time Series, 1959 - 1980)

	Expenditures (000 Constant 1980 US $)							Manpower (Workers)							
Country	1959	1962	1965	1968	1971	1974	Average 1977-80	1959	1962	1965	1968	1971	1974	1977	1980
Argentina	4,513	5,642	22,149	31,308	39,212	23,879	37,412	100	165	260	286	350	360	359	359
Chile	564	618	2,768	5,217	8,922	6,495	10,176	80	91	500	500	800	649	748	847
Paraguay	101	183	387	547	564	498	780	5	10	20	30	36	42	83	124
Uruguay	564	1,129	1,108	1,305	1,409	1,338	2,096	20	30	40	50	60	70	102	133
Temperate S.A.	5,741	7,572	26,413	38,378	50,106	32,210	50,464	205	296	820	866	1,246	1,121	1,292	1,463
Bolivia	282	615	387	653	383	249	1,370	48	60	73	84	81	70	87	120
Brazil	22,851	33,008	42,358	81,403	129,610	179,570	285,039	1,688	1,916	2,196	4,275	6,972	12,600	11,641	14,428
Colombia	5,924	6,318	6,424	4,696	7,514	7,640	12,593	140	161	224	287	350	425	515	609
Ecuador	564	1,723	1,583	2,087	2,348	2,292	3,778	50	115	130	145	160	270	327	387
Peru	845	3,104	9,303	5,011	5,870	5,922	9,491	80	252	420	600	780	960	1,152	1,344
Venezuela	16,363	16,589	15,863	15,889	15,027	12,799	21,097	340	355	450	622	675	735	901	1,067
Tropical S.A.[1/]	47,296	61,971	76,676	110,835	163,051	210,557	336,702	2,369	2,888	3,528	6,073	9,108	15,211	14,769	18,135
Costa Rica	902	902	1,007	1,305	3,005	2,254	3,531	40	40	38	59	104	105	155	205
El Salvador	479	564	674	679	704	1,146	1,795	36	55	81	91	106	140	212	283
Honduras	394	423	369	664	751	859	1,346	35	40	40	50	63	75	164	253
Mexico	2,538	3,668	6,368	8,871	10,589	19,103	29,929	200	250	220	460	800	1,300	1,843	2,115
Nicaragua	507	704	1,038	888	939	763	1,195	16	24	32	28	30	30	43	49
Jamaica	72	94	142	186	240	362	464	126	158	159	266	426	723	949	957
Caribbean[2/]	8,414	10,931	16,509	21,660	27,912	42,118	65,807	779	975	980	1,641	2,630	4,082	5,790	6,643
Regional Total	61,451	80,474	119,598	170,873	241,069	284,885	452,973	3,353	4,159	5,328	8,580	12,984	20,414	21,851	26,241

1/ Includes adjustment for missing countries (plus 1%)

2/ Includes adjustment for missing countries based on estimates (% of subtotals):

Barbados	2
Cuba	25
Guatemala	10
Haiti	19
Panama	9
Trinidad & Tobago	5
Other	2
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QUESTIONNAIRE RESPONSES

Western Europe

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Ing. Agr. José Sosa Dias, Encargado de Dirección, Dirección de Asistencia Técnica, Minesterio de Agricultura y Pesca, Uruguay.

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Appendix Table 3: Publications by Commodity, 1972-75 and 1976-79, for 26 LDC's

Country	Wheat		Rice		Maize		Cotton		Sugar		Soybeans		Cassava		Field Beans		Citrus		Cocoa		Potatoes		Sweet Potatoes		Vegetables	
	72-75	76-79	72-75	76-79	72-75	76-79	72-75	76-79	72-75	76-79	72-75	76-79	72-75	76-79	72-75	76-79	72-75	76-79	72-75	76-79	72-75	76-79	72-75	76-79	72-75	76-79
Egypt	196	157	76	57	203	181	231	188	62	40	23	44	0	0	119	87	65	135	0	0	36	46	15	10	163	201
Ghana	2	0	13	9	21	19	4	1	7	6	4	12	10	5	2	5	3	3	89	65	0	0	8	1	18	13
Kenya	10	12	7	5	52	69	9	3	9	12	2	8	3	9	12	16	4	1	0	0	1	5	1	2	11	12
Nigeria	5	13	55	66	149	193	32	24	19	23	32	37	28	83	14	15	4	7	60	58	2	0	38	59	113	169
Sudan	13	11	0	4	16	19	38	20	5	16	2	2	0	1	21	9	7	3	0	0	0	1	0	0	25	31
Tanzania	6	1	6	6	21	16	14	3	7	3	9	12	3	3	12	2	0	0	2	0	0	0	3	1	4	4
Tunisia	6	3	0	0	0	1	0	0	0	2	0	3	0	0	2	3	10	4	0	0	0	3	0	0	9	9
Uganda	2	0	1	0	19	8	16	9	4	4	2	2	1	3	7	1	0	0	14	0	10	0	0	0	14	3
Bangladesh	6	17	80	134	3	9	1	6	8	22	2	15	0	0	2	1	4	4	0	0	18	52	3	4	24	15
India	1204	1455	1829	2153	1324	1775	408	412	546	645	292	329	39	90	139	176	251	330	14	28	261	400	36	57	1447	1748
Indonesia	0	1	61	108	12	29	0	5	8	10	6	11	3	6	0	3	0	3	13	18	1	9	0	1	8	25
Korea (South)	16	15	177	166	11	23	0	1	6	4	18	36	0	0	4	1	5	15	0	0	9	17	3	5	17	20
Malaysia	0	1	36	17	26	9	0	0	8	3	9	20	6	30	3	7	4	2	14	24	10	1	2	0	10	34
Pakistan	107	92	41	70	52	55	47	74	29	14	4	10	0	0	3	3	12	11	0	0	15	23	0	3	36	32
Philippines	6	3	381	534	58	75	4	10	22	48	15	36	1	9	4	12	17	6	1	1	4	3	10	14	20	32
Sri Lanka	0	0	41	41	6	6	1	1	4	1	2	8	2	4	2	3	1	1	2	1	9	0	1	0	3	4
Taiwan	10	13	183	253	15	44	1	0	94	87	31	56	1	6	4	4	12	17	0	0	4	14	14	34	25	82
Thailand	2	2	50	91	14	28	8	8	1	7	19	24	1	7	0	3	12	0	1	0	1	3	0	0	11	12
Turkey	29	25	6	1	6	17	11	11	24	10	0	4	0	0	7	7	23	39	0	0	6	16	0	0	28	56
Argentina	28	46	3	2	90	67	9	4	67	43	15	25	0	1	6	6	27	32	0	0	41	26	8	3	49	18
Brazil	84	108	103	152	188	383	63	87	76	167	118	368	13	49	119	150	57	83	113	75	30	30	4	2	157	181
Chile	50	74	3	7	31	17	0	1	4	11	9	5	0	0	16	16	9	2	0	1	22	25	0	0	20	28
Colombia	2	6	20	24	37	47	15	12	15	16	16	15	23	87	21	55	3	2	5	7	12	13	0	0	29	34
Mexico	62	49	10	29	65	93	5	8	13	70	8	10	1	5	11	22	9	8	3	3	9	8	2	2	33	27
Peru	15	2	23	6	43	8	15	4	18	24	10	7	4	2	4	1	8	2	2	0	52	132	2	0	14	10
Venezuela	2	3	5	6	38	43	7	10	19	21	9	6	18	18	23	11	9	11	5	3	12	7	1	0	25	22

Appendix Table 3: (Continued)

Country	Banana		Coffee		Groundnut		Coconut		Cattle		Swine		Poultry		Other Livestock		Total*	
	72-75	76-79	72-75	76-79	72-75	76-79	72-75	76-79	72-75	76-79	72-75	76-79	72-75	76-79	72-75	76-79	72-75	76-79
Egypt	3	18	1	0	15	29	1	0	83	154	15	19	78	100	90	189	3270	3759
Ghana	3	4	0	2	7	9	0	1	9	7	6	5	4	5	20	15	457	412
Kenya	5	4	107	126	3	5	0	7	126	194	13	8	11	19	40	68	969	1301
Nigeria	5	18	25	16	48	49	0	1	104	134	41	40	41	62	74	144	1683	2641
Sudan	1	2	1	0	10	18	0	0	29	57	1	0	5	6	25	55	393	532
Tanzania	0	1	16	10	4	2	4	0	26	28	1	0	7	7	4	17	359	336
Tunisia	0	0	0	0	0	0	0	0	2	6	0	0	0	0	2	4	92	135
Uganda	2	1	3	2	11	3	0	0	65	19	3	1	4	3	8	5	405	179
Bangladesh	5	0	1	0	5	8	4	2	19	17	0	0	3	5	20	21	373	584
India	91	130	130	146	407	459	141	156	676	1365	194	280	267	456	539	873	21334	30068
Indonesia	2	1	10	11	5	7	0	14	9	18	3	5	5	8	4	3	402	797
Korea (South)	0	0	0	0	0	1	0	0	26	60	13	43	11	22	6	16	761	991
Malaysia	2	1	1	1	10	9	11	24	35	54	5	21	11	26	18	47	448	459
Pakistan	2	1	0	0	2	4	1	0	17	20	2	3	5	8	7	11	782	1016
Philippines	14	42	1	1	6	17	24	62	18	30	15	20	8	11	6	11	924	1682
Sri Lanka	1	4	1	2	1	3	48	35	24	24	3	8	3	4	14	10	449	411
Taiwan	6	7	0	1	12	7	2	3	10	19	35	52	4	24	3	5	922	1301
Thailand	3	1	0	1	8	14	0	7	3	20	6	12	0	3	4	5	459	715
Turkey	1	0	0	1	0	3	0	0	22	41	1	5	8	11	67	68	601	797
Argentina	1	3	0	0	17	6	0	0	62	94	5	27	7	6	57	67	1208	1455
Brazil	33	40	144	173	29	46	5	12	190	284	48	82	24	35	76	122	3505	5798
Chile	2	0	0	1	0	0	0	0	37	74	17	31	8	14	12	62	662	963
Colombia	7	5	35	37	1	2	1	2	27	111	12	26	5	10	12	27	515	964
Mexico	3	5	1	4	3	8	3	2	61	249	34	41	21	35	37	84	713	1331
Peru	3	1	8	1	2	1	0	0	18	24	5	3	3	7	11	13	416	390
Venezuela	12	9	2	4	11	16	4	2	59	114	8	10	11	21	43	45	721	929

*Total includes publications in fields which are not detailed in this table.

Appendix Table 4: Research Expenditures by Commodity, 1972 and 1976 (million 1980 US$)

Country	Wheat		Rice		Maize		Cotton		Sugar		Soy		Cassava		Beans	
	72	76	72	76	72	76	72	76	72	76	72	76	72	76	72	76
Egypt	4.66	3.41	.87	.60	.62	.50	1.49	1.11	.52	.31	.25	.44	.00	.00	1.04	.70
Ghana	.10	.00	.31	.53	.13	.30	.05	.03	.12	.26	.09	.68	.07	.09	.04	.22
Kenya	.37	.49	.13	.10	.25	.36	.09	.03	.12	.17	.03	.15	.02	.05	.16	.24
Nigeria	.41	2.84	2.16	6.98	1.55	5.40	.71	1.43	.55	1.79	1.20	3.75	.34	2.69	.42	1.21
Sudan	.94	.78	.00	.14	.15	.17	.75	.38	.13	.40	.07	.07	.00	.01	.56	.23
Tanzania	.58	.08	.28	.23	.26	.16	.36	.07	.24	.09	.40	.45	.04	.04	.42	.06
Tunisia	1.03	.54	.00	.00	.00	.02	.00	.00	.00	.13	.00	.25	.00	.00	.13	.20
Uganda	.12	.00	.03	.00	.14	.13	.25	.32	.08	.18	.05	.12	.01	.06	.15	.05
Total Africa	8.20	8.14	3.78	8.58	3.09	7.05	3.71	3.37	1.77	3.33	2.11	5.91	.48	2.93	2.92	2.91
Bangladesh	.14	1.48	.89	5.64	.01	.10	.01	.14	.07	.68	.02	.60	.00	.00	.02	.03
India	13.15	17.89	9.67	12.81	1.85	2.79	1.21	1.38	2.12	2.82	1.48	1.88	.06	.16	.56	.80
Indonesia	.00	.22	2.27	11.52	.12	.82	.00	.30	.22	.78	.21	1.12	.03	.20	.00	.24
Korea (South)	1.79	1.33	9.60	7.14	.16	.26	.00	.02	.24	.16	.94	1.49	.00	.00	.16	.03
Malaysia	.00	.11	1.59	.91	.30	.13	.00	.00	.26	.12	.38	1.03	.08	.49	.10	.29
Pakistan	2.06	12.44	.38	4.58	.13	.95	.25	2.72	.20	.67	.04	.63	.00	.00	.02	.25
Philippines	.13	.05	4.02	4.40	.16	.16	.02	.05	.17	.29	.15	.28	.003	.02	.03	.08
Sri Lanka	.00	.00	1.00	.77	.04	.03	.01	.01	.07	.01	.05	.14	.01	.02	.04	.04
Taiwan	.21	.43	1.86	4.01	.04	.18	.01	.00	.70	1.02	.30	.85	.003	.03	.03	.05
Thailand	.23	.28	2.81	6.25	.21	.51	.25	.31	.04	.35	1.02	1.58	.02	.15	.00	.16
Turkey	3.77	2.84	.38	.06	.10	.25	.39	.34	1.11	.40	.00	.21	.00	.00	.34	.29
Total Asia	21.48	37.07	34.47	58.09	3.12	6.19	2.15	5.27	5.20	7.32	4.59	9.82	.22	1.07	1.30	2.25
Argentina	6.72	6.66	.35	.14	2.77	1.24	.59	.16	5.73	2.22	1.67	1.68	.00	.02	.53	.32
Brazil	9.09	8.58	5.39	5.84	2.60	3.89	1.85	1.88	2.93	4.72	5.92	13.56	.21	.58	4.74	4.38
Chile	2.79	2.88	.08	.13	.22	.08	.00	.01	.08	.15	.23	.09	.00	.00	.33	.23
Colombia	.38	.58	1.83	1.12	.89	.58	.77	.32	1.01	.55	1.40	.67	.64	1.24	1.46	1.95
Mexico	5.61	2.03	.44	.58	.75	.49	.12	.09	.42	1.03	.34	.19	.01	.03	.37	.33
Peru	1.57	.13	1.17	.19	.58	.07	.43	.07	.67	.57	.49	.22	.06	.02	.15	.02
Venezuela	.16	.40	.20	.39	.40	.74	.16	.37	.55	1.00	.34	.37	.22	.36	.69	.54
Total Latin America	26.33	21.27	9.45	8.40	8.21	7.10	3.92	2.89	11.39	10.25	10.39	16.79	1.14	2.25	8.27	7.79
International Centers	1.63	2.49	3.89	7.27	1.98	2.75	-	-	-	-	-	-	.66	1.02	.98	2.25

Appendix Table 4: Research Expenditures by Commodity, 1972 and 1976 (continued)
(million 1980 US$)

Country	Citrus		Cocoa		Potatoes		Sweet Potatoes		Vegetables		Bananas		Coffee		Groundnut		Coconut	
	72	76	72	76	72	76	72	76	72	76	72	76	72	76	72	76	72	76
Egypt	.52	.99	.00	.00	.18	.21	.08	.05	.77	.87	.02	.12	.03	.00	.09	.17	.01	.00
Ghana	.05	.12	1.61	2.91	.00	.00	.08	.03	.18	.32	.04	.15	.00	.28	.09	.29	.00	.04
Kenya	.05	.01	.00	.00	.01	.04	.01	.02	.08	.10	.06	.05	4.63	5.98	.03	.05	.00	.10
Nigeria	.11	.51	1.79	4.67	.03	.00	.65	2.73	1.83	7.39	.12	1.20	2.37	4.09	1.03	2.83	.00	.08
Sudan	.17	.07	.00	.00	.00	.01	.00	.00	.22	.44	.02	.04	.08	.00	.19	.34	.00	.00
Tanzania	.00	.00	.07	.00	.00	.00	.06	.02	.08	.06	.00	.02	1.79	.94	.10	.04	.14	.00
Tunisia	.58	.24	.00	.00	.00	.11	.00	.00	.31	.32	.00	.00	.00	.00	.00	.00	.00	.00
Uganda	.00	.00	.30	.00	.00	.00	.00	.00	.16	.08	.04	.04	.20	.30	.17	.10	.00	.00
Total Africa	1.48	1.95	3.77	7.58	.22	.38	.88	2.84	3.64	9.58	.30	1.62	9.10	11.59	1.71	3.82	.15	.23
Bangladesh	.03	.12	.00	.00	.09	.96	.01	.07	.11	.26	.03	.00	.03	.00	.03	.18	.03	.06
India	.92	1.36	.06	.13	.60	1.04	.08	.15	3.16	4.30	.30	.49	1.66	2.10	1.17	1.49	.57	.71
Indonesia	.00	.22	.37	1.46	.02	.42	.00	.05	.12	1.10	.05	.07	.90	2.83	.10	.41	.00	1.13
Korea (South)	.19	.45	.00	.00	.21	.32	.07	.09	.38	.36	.00	.00	.00	.00	.00	.02	.00	.00
Malaysia	.12	.07	.47	.98	.00	.02	.04	.00	.18	.75	.06	.03	.11	.13	.24	.26	.37	.98
Pakistan	.08	.50	.00	.00	.06	.60	.00	.09	.14	.87	.01	.04	.00	.00	.01	.14	.007	.00
Philippines	.12	.03	.008	.006	.02	.01	.05	.05	.09	.11	.09	.22	.03	.02	.03	.08	.19	.39
Sri Lanka	.02	.01	.04	.01	.10	.00	.01	.00	.03	.03	.02	.05	.06	.09	.01	.03	.89	.50
Taiwan	.08	.19	.00	.00	.02	.10	.06	.24	.11	.54	.04	.07	.00	.04	.07	.06	.02	.04
Thailand	.47	.00	.04	.00	.02	.09	.00	.00	.26	.34	.11	.04	.00	.17	.25	.52	.00	.37
Turkey	1.01	1.49	.00	.00	.17	.39	.00	.00	.73	1.27	.04	.00	.00	.13	.00	.09	.00	.00
Total Asia	3.04	4.45	.98	2.59	1.31	4.01	.33	.74	5.30	9.93	.74	1.01	2.77	5.50	1.92	3.29	2.07	4.17
Argentina	2.18	1.56	.00	.00	2.09	.80	.41	.09	2.35	.52	.07	.13	.00	.00	1.08	.23	.00	.00
Brazil	2.07	2.22	4.50	2.19	.69	.51	.09	.03	3.40	2.88	1.09	.97	18.20	16.05	.83	.96	.20	.35
Chile	.17	.03	.00	.01	.26	.21	.00	.00	.22	.22	.03	.00	.00	.05	.00	.00	.00	.00
Colombia	.19	.06	.35	.25	.48	.31	.00	.00	1.09	.66	.40	.15	7.72	4.17	.05	.05	.07	.07
Mexico	.27	.11	.10	.05	.17	.07	.04	.02	.60	.22	.08	.06	.11	.19	.07	.09	.10	.03
Peru	.28	.04	.08	.00	1.16	1.87	.04	.00	.29	.13	.10	.02	.98	.08	.06	.02	.00	.00
Venezuela	.25	.50	.15	.15	.21	.20	.02	.00	.41	.59	.30	.37	.19	.63	.24	.57	.12	.10
Total Latin America	5.41	4.52	5.17	2.65	5.05	3.96	.60	.14	8.37	5.22	2.07	1.70	27.19	21.17	2.32	1.92	.49	.55
International Centers	-	-	-	-	1.46	2.83	-	-	-	-	-	-	-	-	.00	.33	-	-

Appendix Table 4: Research Expenditures by Commodity, 1972 and 1976 (continued) (million 1980 US$)

Country	Cattle 72	Cattle 76	Swine 72	Swine 76	Poultry 72	Poultry 76	Other Livestock 72	Other Livestock 76	Other Crops 72	Other Crops 76
Egypt	1.37	2.33	.25	.29	1.29	1.51	1.49	2.86	5.46	5.85
Ghana	.31	.59	.21	.42	.14	.42	.68	1.27	1.43	3.50
Kenya	3.25	5.48	.33	.23	.28	.54	1.03	1.92	2.57	3.72
Nigeria	5.87	20.39	2.32	6.09	2.32	9.43	4.18	21.91	8.25	40.02
Sudan	1.47	2.80	.05	.00	.25	.29	1.26	2.70	1.90	2.50
Tanzania	1.73	1.57	.07	.00	.47	.39	.27	.95	2.58	2.26
Tunisia	.24	.75	.00	.00	.00	.00	.24	.50	1.35	2.24
Uganda	2.65	1.71	.12	.09	.16	.27	.33	.45	1.71	1.90
Total Africa	16.89	35.63	3.34	7.11	4.91	12.86	9.48	32.57	25.24	62.01
Bangladesh	.30	1.03	.00	.00	.05	.30	.32	1.27	.49	2.80
India	5.14	11.68	1.47	2.40	2.03	3.90	4.10	7.47	15.51	26.13
Indonesia	.48	2.76	.16	.77	.27	1.23	.21	.46	2.48	14.13
Korea (South)	2.03	3.71	1.01	2.66	.86	1.36	.47	.99	6.29	6.20
Malaysia	2.22	4.17	.32	1.62	.70	2.01	1.14	3.63	2.77	1.82
Pakistan	.23	1.88	.03	.28	.07	.75	.09	1.04	.99	10.04
Philippines	.27	.36	.23	.24	.13	.13	.09	.13	.81	1.54
Sri Lanka	.84	.65	.11	.22	.11	.11	.49	.27	1.80	1.25
Taiwan	.15	.43	.51	1.19	.06	.55	.04	.11	1.23	2.41
Thailand	.24	1.97	.49	1.19	.00	.30	.32	.49	4.68	8.48
Turkey	1.99	3.24	.09	.40	.72	.87	6.07	5.37	6.03	7.01
Total Asia	13.90	31.88	4.41	10.95	4.98	11.50	13.35	21.24	43.08	81.79
Angentina	10.36	9.48	.84	2.72	1.17	.61	9.53	6.76	22.01	18.15
Brazil	14.31	15.70	3.62	4.53	1.81	1.94	5.72	6.75	25.36	32.22
Chile	1.44	2.01	.66	.84	.31	.38	.47	1.68	3.02	2.96
Colombia	3.55	7.46	1.58	1.75	.66	.67	1.58	1.81	5.24	5.24
Mexico	3.84	7.16	2.14	1.18	1.32	1.01	2.33	2.42	3.69	3.01
Peru	1.31	1.12	.36	.14	.22	.33	.80	.61	2.09	1.22
Venezuela	3.35	10.66	.45	.93	.23	1.96	2.44	4.30	4.23	9.39
Total Latin American	38.16	53.58	9.65	12.10	5.71	6.89	22.87	24.32	65.64	72.19
International Centers	-	-	.38	.20	-	-	.03	3.27	-	-