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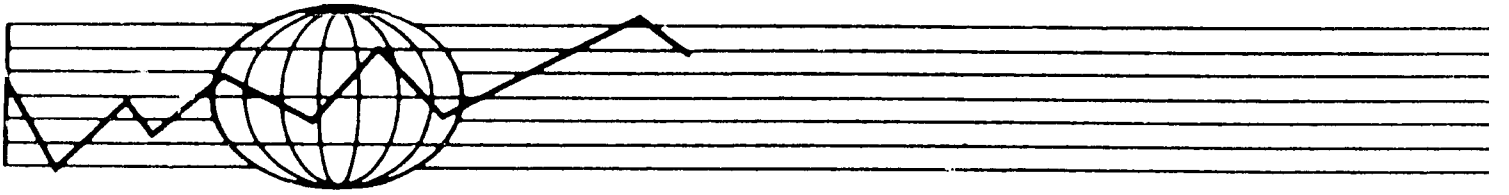

COMPLETION REPORT OF THE ASIAN AGRICULTURAL RESEARCH PROJECT (CONTRACT NO. AID/ASIA-C-1456)

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Asia Agricultural Research Review

EXECUTIVE SUMMARY

Background of the Project

This executive summary covers work conducted under the U.S. Agency for International Development - University of Minnesota Asia Agricultural Research Review Project (Contract No. AID/ASIA-2-1456). The Agricultural and Applied Economics Department of the University of Minnesota was the principle contractor with Yale University taking an important secondary role.

Discussions between the US/AID and the UM that led to the project were initiated in the fall of 1979. Research under the contract was initiated in June of 1980. It was revised and extended in September 1981. The objectives of the US/AID Asia Bureau in supporting the research to be conducted under the contract included:

1. To find out if they were investing in a productive activity.
2. To find the income distribution impact of investments in research.
3. To develop ideas on what to do next--different crops, different institutions, different strategies.

Framework and Methodology:

The country studies started with short missions to Philippines, Pakistan and Indonesia by senior scientists from Minnesota and Yale to obtain an overview on the performance of the national agricultural research systems and the role of AID in supporting the development of the national research systems. The missions were also intended to lay the groundwork for a longer term in depth studies of the returns to research investment. These visits were supplemented by consulting experience of senior scientists in Bangladesh and India during the period of the project.

Longer term analytical studies were carried out in all six countries to calculate the productivity of research investments and the impacts of research on different groups in society. The studies in Pakistan and Indonesia were based on data collected by graduate students stationed there. The data from Thailand was collected during a shorter visit by study staff. The Bangladesh, the Philippines and India studies were conducted using data that was available in the United States.

The analysis of the productivity and income distribution effects of research employed three types of analytical tools. These included the index number approach, the production function approach, and the cost function approach.

The theories of induced technological and institutional change provided a framework for the analysis of growth and institutional change of the research systems.

Impact of Agricultural Research on Output and Productivity

The rates of return studies indicate that research was a very productive investment. Aggregate production function and cost function studies using total research expenditure as the independent variable showed a positive and large impact of research with the possible exception of Bangladesh where the different models used in the analysis did not give consistent results. Single commodity studies produced extremely high rates of return in Indonesian rice research and wheat research in Pakistan. Rates of return to maize research in Pakistan was more moderate.

Income Distribution -

The cost function approach indicates a positive but small shift in the demand for labor due to research expenditure in India, Thailand, and Indonesia.

Adoption of foodgrain HYVs increased demand for labor in India and Indonesia. Microstudies of HYVs confirms this in most countries. Research appears to have decreased the demand for labor only in the Philippines. Local research led to positive and large shift in demand for machinery and fertilizer.

New technology has reduced the cost of the major foodgrains - wheat and rice. The amount of the reduction and who benefits from the reduction depends on the price policies pursued by governments. These commodities make up a major portion of the budget of the poor both in the cities and countryside and a small portion of the budget of the rich. So this price decline should imporve income distribution.

The net effect of the cost reductions and shifts in the demand for inputs depends on price and trade policies. Simulations using Indian data and coefficients indicate that a 20 percent reduction in the cost of production of the major foodgrains will have positive effect on income distribution in the absence of price supports or the possibility of exporting all of the increase. If it can be exported, then there will be negative income distribution impacts.

Impact of USAID:

US/AID programs in support of agricultural research resulted in an increase in total investment in agricultural research made in the group of countries that were studied. It has helped increase the share of research resources devoted to foodgrain research. More recently support by the US/AID has also increased research on pulses, oilseeds and millets.

AID programs have also contributed to a number of institutional changes: the autonomy of research systems from regular civil service rules; the establishing agricultural research councils; the strengthening of regional research stations and the promoting farming systems research.

Recommendations for AID:

1. The high rates of return indicate continuing underinvestment in agricultural research. Therefore agricultural research remains a productive area for AID investment.

2. There are indications of a continuing misallocation of research resources by many National Agricultural Research Systems (NARS).

a. AID should try to strengthen capacity for planning and management by encouraging the allocation of resources to those activities by the NARS. This will usually involve strengthening research capacity of the agricultural research system.

b. Underinvestment in research is generated for some of the major foodgrains. There may be overinvestment in some minor crops like wheat and soybeans in some countries. Livestock and fisheries research has received little attention in several of the countries reviewed. Support for research on cash crops can be justified in some countries on the grounds of employment generation and foreign exchange earnings. With noncommodity area research in the social sciences and in soil and water management appear to have been neglected.

3. It is time to make a shift in the use of AID resources from investment in facilities and equipment to investments which will build human capital and strengthen information flows. More resources need to be invested in the graduate programs of local agricultural universities and foreign training at the Ph.D. level. Another productive investment is in the networks and information flows which keep scientists productive. Communications with other scientists is the lifeblood of science but governments which are presssed for foreign exchange put low priority on academic journals, trips by scientists to seminars, and foreign training. AID money which has supported activities of organizations

like the CGIAR, ADC, and American universities to improve such communication has been well spent.

4. Closer linkages are needed between scientists and farmers to make sure farmers can articulate their demands and that research moves rapidly from the scientists to farmers. In addition if the clients--particularly poor clients--have more power the efficiency of the research system should improve, the allocation of resources would change and scientists might do more useful research. Government research will be able to generate more political support for their budget. AID can provide incentives to research systems to develop stronger ties to farmers. The matching grant system or the research assistance support and implementation groups that we have proposed are possibilities that we would urge AID to consider. Less radical measures include evaluating research projects on the basis of their impact on farmers.

5. AID should place a higher priority on encouraging the growth of research and development activities by the private sector and the support of research by commodity groups. There may be opportunities for aid to partially fund research by these groups. Probably more important is AID financed research and which identifies the legal and other institutional constraints governments impose in the development of private sector agricultural research.

Additional Output of Project

In addition to the research conducted the project had an important educational role. Our graduate students conducted their research in collaboration with local researchers in Indonesia and Pakistan and increased the local capacity to provide empirical analysis for research administrators. In addition Minnesota started the Agricultural Research Policy Seminar during this project. The seminar, which annually attracts 20 to 30 research leaders from developing

countries and AID, was organized by Drs. Pray and Ruttan and used material taken from our research on this project.

Another impact has been the participation of Drs. Ruttan and Pray in AID's internal discussions on funding research projects. Pray was also involved in AID consultancies to evaluate Bangladesh and Philippine research projects and to write the economic justification for an Indian agricultural research project.

Chapter 1 Impact of Research on Agricultural Productivity

Output and Productivity

This chapter examines the impact of investment in government agricultural research programs on agricultural growth in India, Bangladesh, Pakistan, Thailand, Indonesia and the Philippines. Table 1.1 brings together available data on output and productivity growth since 1950. All of these countries had fairly rapid growth in agricultural output by historical standards. Bangladesh and India had the lowest growth rates, 2.4 and 2.5 percent annually. Indonesia is next at 2.8 percent followed by Pakistan, Thailand and the Philippines which grew more than 3 percent annually.

Total factor productivity measures are available for four of the countries in this study. They are less impressive and less regular than the output growth measures. Increases in conventional inputs including fertilizer and irrigation accounted for most of the output growth in all four countries. For the period 1950-76 in Thailand conventional inputs accounted for 62 to 73 percent of output growth (Damrongsak, 1978). Bangladesh, Pakistan and the Philippines experienced a decline in productivity during the 1950's. Indonesia experienced a similar decline in the 1959-66 period. Pakistan and Indonesia experienced rapid productivity growth (greater than 1 percent) during the Green Revolution period. The Philippines series only goes up to the early Green Revolution period (1969) but grew at 1.2 percent. Bangladesh is the only country where productivity growth during the Green Revolution period (1971-81) does not quite reach 1 percent.

In addition to the uneven pattern of productivity growth over time, productivity growth was uneven across countries and regions. Table 1.2 shows the differences in growth rates of 15 Indian states during three time periods.

Table 1.1. Growth Rates of Output, Value Added and Total Productivity of Agriculture in Selected Countries, Various Periods

Country and Period	Growth rate			
	Output	Value-added	Total productivity	
			Output basis	Value-Added basis
		percent annually		
Bangladesh				
1948-1960	0.41		-0.74	
1960-1971	2.12		0.29	
1971-1981	3.53		0.97	
1948-1981	2.40		0.78	
1970-1981	2.40			
Pakistan				
1953/54-59/60		0.90		-1.50
1959/60-64/65		4.70		0.80
1964/65-69/70		8.20		6.90
1969/70-74/75		0.50		-1.60
1974/75-78/79		3.70		2.00
1953/54-78/79		3.40		1.10
1980-1981	2.6			
India				
1949/50-64/65	3.10			
1964/65-79/80	2.70			
1949/50-79/80	2.50			
1970-1981	1.90			
Thailand				
1950-60	3.92			
1961-66	6.30			
1967-71	3.06			
1972-76	3.75			
1976-81	4.50			
Indonesia				
1950-1958	.	3.93	.	0.45
1959-1966	.	1.64	.	-1.99
1967-1978	.	3.79	.	1.57
1950-1978	.	2.82	.	0.60
1970-1981	3.8			
The Philippines				
1950-1956	5.2	5.2	1.5	1.7
1956-1959	2.0	1.7	-1.4	-1.1
1959-1969	3.8	3.6	0.8	1.2
1950-1969	4.0	3.8	0.7	1.0
1970-1981	4.9			

Sources: Indonesia, Ahmed (1982), David and Barker (1979:131) for the Philippines, Pray and Ahmed (1984) for Bangladesh, Wizarat (1981) for Pakistan, World Bank (1981) India, Damrangsak (1978) for Thailand. The last period in each country is from the World Bank, 1983.

* Crops only - not animals.

Table 1.2. Statewise Growth in Agricultural Productivity

	1953-56 to 1956-61	1958-61 to 1963-65	1963-65 to 1969-72
Andhra Pradesh	.85	.11	-1.05
Assam	-2.27	- .18	3.98
Bihar	1.40	.32	- .82
Gujarat	.74	2.81	4.78
Haryana	2.41	- .70	16.10
Kerala	1.97	-1.25	- .67
Madhya Pradesh	2.01	.05	-1.52
Maharashtra	2.11	- .93	-2.13
Mysore	1.03	.69	.27
Orissa	-1.34	1.93	1.30
Punjab	2.41	.52	13.40
Rajasthan	.09	- .99	12.70
Tamil Nadu	1.49	1.43	.61
Uttar Pradesh	.43	.66	1.93
West Bengal	-2.12	2.67	- .36

Source: Robert Evenson and Dayanath Jha, "The Contribution of Agricultural Research System to Agricultural Production in India." Indian Journal of Agricultural Economics, Vol. XXVIII, No. 4.

Productivity growth during the last period varied from 16 percent in the Punjab to -2 percent in Maharashtra. This regional diversity is true for the other five case study countries.

The Growth of Asian Agricultural Research Systems

The period since World War II has been one of rapid growth for most Asian research systems. Table 1.3 shows the index numbers of growth in real government research expenditure of the six case study countries since 1959. Two distinct patterns are apparent. India, the Philippines and Pakistan reprsent the first pattern. Their research had fairly rapid growth - the Pakistan system doubled in size, the Philippines tripled and Indian research increased almost five times. Thailand, Bangladesh and Indonesia represent the second group -

Thailand grew by a factor of 13, Bangladesh by a factor of 15 and Indonesia by a factor of more than 50. The early numbers in Indonesia are not reliable, but it is clear that there was an enormous increase in resources. The level of dollar expenditure in 1980 in Table 1.3 indicates that these last three countries were building rapidly from a very low base, while India, Pakistan and the Philippines had large research programs in 1959 relative to the last three.

In expenditure and manpower, India had by far the largest research program in 1980. It was followed by Indonesia, then Pakistan, Bangladesh and Thailand, which were all about the same size. The program in the Philippines was the smallest. It was about half the size of the next biggest program in terms of both expenditure and scientific manyears. The last line in Table 1.3 shows that research expenditures as a percent of agricultural GDP were highest in 1980 in Indonesia and lowest in the Philippines. These numbers for the Philippines may be somewhat misleading. The IRRI budget has not been included although it does most of the rice research for the Philippines.

Data on research expenditure by the private sector in most of these countries is not available. Discussions with government and private sector scientists plus a few scattered figures present the following picture. After World War II, a few private sector producers' organizations like the Indian tea producers and a few companies in the processing industry like sugar mills and tobacco companies did some research. They appear to have continued to invest in research but they invested much less than Asian governments invested. There was no real growth in private sector research expenditure until the mid-1960s when suppliers of fertilizer, pesticides and seeds started to do applied research in India, the Philippines and Pakistan. At present, input supply companies have active research programs in India, the Philippines and Thailand. There is a

Table 1.3 Government Research Expenditure and Manpower

	India	Indonesia	Philippines	Thailand	Pakistan	Bangladesh
			Index of Real Research Expenditures 1959=100			
1959	100	100	100	100	100	100
1962	119	400	131	273	114	117
1965	165	834	153	482	146	203
1968	184	1203	175	622	177	323
1971	266	1540	198	756	188	387
1974	269	1423	246	739	187	438
1977	418	7487	311	1517	191	660
1980	484	5887	343	1392	217	1546
			Expenditures (000 Constant 1980 US$)			
1980	120167	33200	9533	21600	29899	27613
			Manpower (SMYs)			
1980	2345	1473	640	1264	1212	1320
			Research Expenditure as a % of Agricultural GDP			
1980	0.29	0.44	0.16	0.26	0.41	0.48

Sources: Research expenditure and index numbers for India, Indonesia, Philippines and Thailand from Judd et al 1983. Bangladesh index is from Pray and Ahmed 1984. Pakistan index is from Nagy 1984. Manpower from Judd et al 1983. Expenditure/Agricultural GDP from Oram and Bindlish 1981.

small amount of private research done on pesticides in Indonesia and on hybrid seeds in Pakistan. At present the input supply companies seem to be doing no research in Bangladesh. The only estimates of private research expenditure have been in India where expenditure is estimated to be less than 10 percent of total agricultural research (Government of India, 1980) and in the Philippines where it was calculated to be about 10 percent in 1970-71 (Philippines, 1971).

USAID financed major agricultural extension and agricultural university projects in the 1950's and 1960's. It also financed a few small research projects in the early 1950's in Southeast Asia. In 1966 it financed its first major agricultural research projects in Northeastern Thailand. The Thai project was followed by projects in India in 1967, Pakistan in 1969, and East Pakistan in 1970. In 1969 AID started to provide assistance to CIMMYT and in 1970 started to finance IRRI's core program. In the 1970's AID launched major new projects to build research institutions in Indonesia, the Philippines and Bangladesh. In 1982 Indonesia was the major recipient of AID funds for research followed by Bangladesh and the Philippines.

Other major donors followed the lead of AID. The World Bank financed its first research project in 1972 in Spain. Bilateral donors from other countries started about this time also. By the late 1970's many countries were investing in research. Oram and Bindlish have gathered the available data which is presented in Table 1.4.

Although foreign donors have played an important role (see Chapter 4), their role should not be overestimated for several reasons. First, the rapid growth of these agricultural research systems started in the 1960's. This was before the bilateral and multilateral donors other than Ford and Rockefeller Foundations invested any money in research. The decision to increase research expenditure was made by the governments of Asia and was not forced upon them by

outside donors. Second, the investment by donors was undoubtedly not a net increase in research resources. Governments substituted some of these funds for local funds which would have gone to research.

Methodology to Determine Impact of Research Systems

In all six countries we have attempted to measure the impact of the research system in increasing agricultural productivity. We have used three different techniques[1/] which vary both in the sophistication of the models and the data required to estimate the parameters of these models. The first approach is called the index number or consumer and producer surplus approach. It uses estimates of the shift in the supply function due to the introduction of new technology to calculate the change in economic surplus. These changes in surplus are then compared with the costs of producing that surplus like expenditures on research and extension in order to calculate a rate of return to those expenditures.

The second approach is the production function approach. In this approach research and extension are two independent variables in the production function and their separate impacts on the output is estimated. When using time series data, it is often necessary to have a productivity index rather than output as the dependent variable because the inputs are so highly correlated. Both of these specifications provide statistical evidence that there is a causal relationship between research expenditures and the output of farmers. The estimated parameters can be used to calculate the marginal product of research expenditure and rates of return to research.

1/ For a detailed discussion of the index number approach and the production function approach see Norton and Davis (1981). For a detailed discussion of the cost function approach, see Binswanger and Quizon, 1983 and Appendix 1.

Table 1.4 Donors to Agricultural Research 1975-81 [1/]

Region and Countries Benefitting Asia and Pacific [3/]	Donor Country or Agency: Australia	Belgium	Canada	France	Germany (Fed Rep)	Scandinavia	Switzerland	UK	USA	FAO/UNDP	IBRD	Others: [4/]	Magnitude of Funds Channeled to Recipient Country [2/]: over 40 m	20-40 mill	10-20 mill	5-10 mill	1-5 mill	under 1 mill
Bangladesh	♦				♦	♦	♦		♦	♦	♦	♦	✓					
Burma											♦						✓	✓
Fiji	♦							♦										
India					♦	♦♦	♦	♦	♦		♦		✓					
Indonesia	♦			♦			♦		♦		♦	♦♦	✓					
Korea (Rep.)					♦				♦	♦	♦				✓			
Malaysia	♦	♦			♦			♦			♦			✓				
Nepal	♦		♦		♦		♦		♦	♦	♦	♦				✓		
New Caledonia	♦			♦				♦									✓	
Papua/N. Guinea									♦									✓
Pakistan	♦				♦	♦	♦		♦	♦	♦				✓			
Philippines	♦				♦			♦	♦	♦	♦	♦			✓			
Polynesia								♦	♦	♦	♦				✓			
Solomon Islands	♦							♦										
Sri Lanka	♦					♦	♦		♦	♦	♦	♦		✓				
Thailand	♦				♦			♦	♦	♦	♦	♦♦		✓				
W. Samoa	♦			♦								♦						
Regional	♦			♦	♦	♦			♦	♦	♦							✓
Asia Total = mill $	66.7	2.5	NA	NA	30.6	2.0	3.2	0.6	88.6	84.0	191.7	1.0	464.8 Total					

Source: Peter A. Oram and Vishva Bindlish, Resource Allocation to National Agricultural Research: Trends in the 1970s Washington: IFPRI 1981.

The third approach estimates a system of cost functions and input supply functions simultaneously and includes a research expenditure variable. The advantage of this approach is that it is possible to separate the effects of shifts in input supply from shifts in input demand which are caused by new technology. It is also possible to estimate the biases in technical change. These advantages are particularly important for the next section on income distribution but these equations also can be used to estimate the marginal product of research and rates of return to research.

The index number and the production function approaches were used to estimate the impact of agricultural research in Pakistan, Bangladesh and Indonesia. The Pakistan study (Nagy, 1984) used time series data with productivity as the dependent variable. Research and extension expenditure lagged over 12 years, percentage acreage under high yielding varieties (HYVs), and rural literacy were the independent variables. Nagy's lagged research and extension variable and percentage average under high yielding varieties were both significant. The Pray and Ahmed (1984) study of Bangladesh used the same procedure and found that lagged research expenditure was a significant explanatory variable but extension was not. Rural literacy was negative in some of the specifications. The authors also pooled district level data for 1977 and 1981. The research variable was not significant but extension expenditure and HYVs were positive and significant. The authors concluded that their district level research variable did not accurately reflect research activity. The Salmon (1984) study of rice research in Indonesia used cross sectional data from the years 1972-77. He found that research on bunded rice[2/] in each province and in neighboring pro-

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2/ In bunded rice there is usually good water control.

vinces had a significant impact on rice productivity as did government extension and input supply service (BIMAS) and rural literacy.

Rates of return to research investment are shown in Table 1.5. The Pakistan rate of return was about 65 percent. In Bangladesh the implied rate of return was over 200 percent. In Indonesia the estimates implied an internal rate of return of over 100 percent. The rates of return to local investment are high because it is not possible to separate benefits from local research from the benefit from the international centers. Thus, some benefits are in fact returns to IARC research. Rates of return using the index number approach were also calculated for Pakistan and Bangladesh. The rates of return to wheat research in Pakistan were about 60 percent while the returns to maize research were about 20 percent. In Bangladesh the returns to all crop research were 32-37 percent. In sum, these estimates indicate high rates of return to investments in research.

The third approach, which estimates a system of supply and demand equations was used in India, Thailand and the Philippines (see Appendix I). Table 1.6 presents the output elasticities estimated from these models. For example, the first row indicates that a 10 percent increase in the acreage under HYVs will lead to a 1 percent increase in rice output. The results for North India (Evenson, 1983) show that HYVs of wheat and rice had a positive effect on the production of wheat and rice but a negative effect on other crops due to substitution of HYVs of wheat and rice for some other crops. In contrast, the Indian research variable had positive and significant impact on other crops (particularly sugarcane and cotton) and a negative effect on wheat and rice. This surprising result is due to the fact that much of the work by Indian wheat and rice scientists was screening and selecting HYVs and developing cultural practices for these varieties. As a result some of the positive impact of the

Table 1.5. Rates of Return to Research

	Method	Commodities	MIRR	IRR
Pakistan	Production Function	Crops and Livestock	64.5%	
	Index No.	Wheat	60-67%	55-62
	Index No.	Maize	19-27%	15-23
Indonesia	Productivity	Rice	100+	
Bangladesh	Productivity	Crops	200	
	Index No.	Crop		32-37%
North India	Systems		60-70%	
Res. & Ext.	Systems		72%	

Sources: Pakistan, Nagy (1984); Indonesia, Salmon (1984); Bangladesh, Pray and Ahmed (1984); and North India, Evenson (1983).

HYV variable should be attributed to local research. In fact, when the interaction terms are taken into account and the impact on the different crops aggregated, Evenson finds a rate of return to local research of 60 to 70 percent.

The Thai case study (Evenson and Setboonsarng, 1984) uses data for a later period, 1967-80. In this case, research had no effect on rice production. It had very strong, positive effects on corn production and negative effects on other crops. Extension had a strong positive impact on corn and other crops, and irrigation had a positive impact on rice and other crops.

The Philippines case study (Quizon, 1981) estimated the influence of research expenditure on total output. We have included only the signs of the coefficients in Table 1.6 because the paper did not calculate the elasticities. Research and irrigation had a positive and significant relationship to output

Table 1.6 Elasticities with Respect to Changes in Research and Extension Expenditure Based on Cost Function

	Total Output	Elasticities of Output Supply				
		Rice	Wheat	Coarse Cereals	Corn	Other Crops
North India 1959-74						
HYV		.109**	.278**	-.074**		-.128*
Indian Research		-.085**	.023	-.102**		.176**
Irrigation		.271*	1.123**	.919**		.276**
Thailand 1967-80						
Research		.010			2.477**	-.777*
Extension		-.062			1.308**	.534**
Irrigation		-.042**			-.007	.084**
Philippines 1948-74						
Research	+**					
Extension	-					
Irrigation	+**					

Sources: North India from Evenson 1983; Thailand from Evenson and Setboonsarng 1984; Philippines from Quizon 1981.

while extension was negative but not significant.

This third approach reaffirms the results from the production function and index number approaches. It provides evidence that research expenditure has increased agricultural output. It also provides evidence of a strong positive relationship between irrigation and output. The evidence on extension is not as consistent. In the Philippines extension had no impact on output. It also had no impact on Thai rice production but it had strong positive effects on corn and other crop production in Thailand.

Conclusions and Recommendations

The evidence presented here indicates that government research has been a productive investment. Rates of return are higher for research than for most public sector investments. This is consistent with evidence from other developing and developed countries. High rates of return suggest there is at present, a substantial underinvestment in national agricultural research systems. The low percentage of agricultural GDP invested in research in all of these countries (less than 0.5 percent) suggests that these countries have the resources necessary to finance more research if they can be mobilized.

This evidence indicates that AID's investment in developing national research systems has been productive. Evidence from the cost function and the production function approaches shows that research is statistically significant more often than extension. Earlier studies suggest a lower rate of return to extension expenditure than research (Evenson and Kislev, 1975). Our results indicate that irrigation is an important investment. Continued AID support for irrigation seems justified. These studies indicate that the IARCs have been productive investments. The value of producer surplus in Pakistan was more than

total investment in CIMMYT and HYV variables were significant in the production function and systems approaches.

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Chapter 2 Impact of Research Investments on Income Distribution

It is important to identify the important groups which benefit from research in order to understand the role these groups play in institutional change. This chapter will concentrate on the impact of new technology on the poor. The stylized facts about poverty in these countries are that poor people live in both urban and rural areas but far more poor people live in rural areas. Although the majority of people in these countries live in rural areas, government policies are generally biased toward the urban areas. In the rural sector, the poor are primarily agricultural laborers and small farmers. As a result, research that benefits the agricultural sector as a whole and research which increases rural wages rather than land rents will improve income distribution.

Impact on Inputs and Research Biases

Most criticism of the green revolution and agricultural technology in LDCs has focused on agricultural input markets. The critics suggest that research has decreased the demand for labor and increased the demand for capital and land. Many of the early critics of the green revolution presented evidence that rural wages were going down while new technology was spreading and attributed that fact to the new technology.

Trends in rural wages in these six countries are mixed. Table 2.1 shows trends in real wages in three countries - Bangladesh, Philippines and India. In each country the 1979 real wages are below their 1965 level. In Bangladesh there are indications that real wages have started to increase in the last few years (World Bank, 1984). In the Philippines real wages continue to decline.

Table 2.1. Index of real wages of agricultural laborers in selected Asian countries (1965=100).[a/]

Year	Japan	South Korea	Malaysia	Philippines[b/]	India	Bangladesh[b/]
1965	100	100	—	100	100	—
1966	104	104	100	101	104	—
1967	111	112	95	102	103	—
1968	125	126	97	93	102	100
1969	132	136	100	84	113	99
1970	138	147	98	79	117	96
1971	179	155	93	78	86	75
1972	162	161	91	—	107	70
1973	170	171	89	—	92	67
1974	178	178	100	70	56	70
1975	197	182	90	—	84	70
1976	191	205	112	—	94	68
1977	195	230	102	—	89	70
1978	201	290	107	—	90	74
1979	202	372	119	—	90	—

a/ Wages of agricultural workers deflated by the consumer price index.

b/ 1965 is the fiscal year 1965-1966 etc.

Source: Herdt and Barker (1985).

Several studies in India suggest that the states in which wages increased during the 1960's and 1970's are the ones in which there has been the most technical progress (Prahladachar, 1982). A.R. Khan's (1984) study of wages in Bangladesh shows a significant positive relationship between the changes in yield per acre and real wages. In the Philippines there seems to be little regional difference in wage trends, all of which were depressed due to inflation during the 1970's.

Despite the early criticism that the green revolution led to more unemployment, there now seems to be consensus among scholars about the green revolution's impact on labor (Griffin, 1978). The HYVs have increased the demand for labor in Asia even in areas where there has been considerable mechanization. The demand for labor has not been growing as fast as the supply of labor. Thus the real income of the agricultural laborer in many South and Southeast Asian countries has been steadily declining over the last 20 years. Mechanized cultivation in Asia started before the green revolution and has not been noticeably speeded up by the introduction of HYVs.

Mechanized cultivation has decreased the demand for labor without increasing productivity. This was a policy encouraged by the government and was independent of the green revolution. Mechanized irrigation in the form of power pumps and tubewells appears to be more closely associated with the green revolution. Its impact has increased the demand for labor because it has allowed for more multiple cropping.

Much of the early criticism of the impact of the HYVs on labor seems to have arisen because critics confused independent trends - specifically, growth in rural population and mechanized cultivation - with the effect of HYVs. A number of recent studies have analyzed the impact of the HYVs on labor utilization. They show that the demand for labor increased but not enough to keep up

with population growth (Barker and Cordova, 1978). As a result, the condition of the landless laborer is better than it would have been in the absence of HYVs, but his position is declining and the HYVs alone cannot reverse this trend.

Previous studies of new technology on income distribution have had two major defects. First, they have not included the effect of shifting acreage to different crops. Second, they have not been able to separate shifts in the demand for inputs due to research from shifts due to other factors. The cost-function approach which Evenson, Binswanger, and Quizon have developed allows one to separate the impact of technology from the impact of exogenous factors such as the shift in supply of labor due to population growth. It allows us to test the hypothesis that it was a shift in labor supply, rather than biased technology which led to a decline in real wages.

Elasticities of input demand from the Philippines, Thailand and North India studies are shown in Table 2.2. These input demand elasticities show the shift in the input demand curve due to a 1 percent change in the variables. The biases are shown by the relative size and the sign of these elasticities. For example, HYV's in North India are biased in favor of fertilizer which is positive and relatively large (.259) and away from farm machinery because an increase in HYV's leads to a decline in the use of farm machinery (-.122).

The results indicate that the research and extension impact on the demand for labor is not consistent across countries and types of research. The research embodied in HYVs in North India and Thai research show that both had a positive but small effect on labor demand. In Salmon's Indonesian study (1984), research appears to have a positive effect although the fit of the model as a whole was not very satisfactory. Khan's (1983) study of Bangladesh also indicated a positive shift in labor demand due to research. In India national

Table 2.2 Elasticities with Respect to Changes in Research and Extension Expenditure Based on Cost Function

	Elasticities of Input Demand			
	Fertilizer	Bullock Labor	Farm Machinery	Labor
North India 1959-74				
HYV	.259**	.012*	-.122**[1/]	.03*
Indian Research	.249**	-.002	.537**[1/]	-.084**
Irrigation	1.203**	.056**	1.851**	.042
Thailand 1967-80				
Research	-.769**		2.460**	.040
Extension	-.064		.776**	-.038
Irrigation	.165**		.2829**	-.035**
Philippines 1948-74				
Research	+**		+**	-**
Extension	+**		+**	+
Irrigation	+		-*	-**

Sources: North India from Evenson 1983; Thailand from Evenson and Setboonsarng 1984; Philippines from Quizon 1981.

[1/] Tractors only.

research expenditures and in the Philippines total expenditure both showed negative relationships with labor demand. In sum, there is no evidence that research in general has a strong consistent negative effect on demand for labor. In India and the Philippines, however, there is evidence that some types of research have had a negative effect on the demand for labor.

The impact of research on the demand for other inputs is fairly consistent across countries. Research increased the demand for farm machinery. An exception was research that produced the rice and wheat HYVs in India. Research had a positive and significant effect on fertilizer use in India and the Philippines but in Thailand it reduced the demand for fertilizer. The elasticities of demand for these inputs with respect to an increase in research are larger than the elasticities of demand for labor in Thailand and India. In the Philippines, research decreased demand for labor while increasing the demand for fertilizer and capital. From this we conclude that research has been biased in favor of fertilizer and capital.

Input supply companies have been major beneficiaries of the growth in research. In Asia this means that benefits have gone both to the government bureaucracy which often runs the input supply business and private companies that manufacture and supply these inputs. The employment generating effect of the input supply activities has not been measured in Asia but is felt to be substantial. Employment in the transportation and distribution of fertilizer and pesticides has certainly added to total employment.

The criticism that has been leveled at the green revolution most consistently is that it has had a negative effect on rural income distribution. There seems to be a consensus that landowners have captured more gains from the HYVs than the tenants and laborers. A study of the distribution of the

increased output from HYVs in the Aligarh district of India showed that 67 percent went to owners of land and capital, 23 percent went to sellers of inputs like fertilizer, and 10 percent went to laborers. This seems to have been typical of all India (Ruttan and Binswanger, 1978). This does not seem to be the result of the biased shift in technology. Relative to the other important technological path for improving agriculture - mechanization - HYVs are clearly land-saving if they are biased at all. There are two reasons that this neutral shift in technology has led to a large increase in the rents to land. First, the supply of labor is relatively elastic compared with the supply of land. Second, the supply of labor is increasing at a very rapid rate. In the absence of HYVs, pressure on land would have been even higher and income distribution more skewed toward landowners.

Technology is neutral among landholders, but existing structural inequities and independent shifts in the supply of factors of production have led to an unequal distribution of the gains. There has been no evidence that there are economies of scale in HVY technology that give big farmers an advantage over small farmers in its use. There is almost no evidence that HYVs have been adopted more slowly on sharecropped or leased land than on owner-operated land. Even some of the critics agree that it is not the technology that has led to unequal distribution of gains. Rather, it is the access to inputs that are rationed by political rather than economic processes that lead to the inequality. Lipton's extensive survey of the literature finds little evidence that there are economies of scale in the use of the new varieties, but he finds "scale economies in product distribution and storage, and in obtaining inputs, are unquestioned, as are higher per-acre costs of administration and extension for small farmers." (Lipton, 1978). HYVs did not cause this situation and they cannot solve it.

The patterns of rural income distribution that emerge from these studies are: 1) Research generally had a positive effect on demand for labor. In India where we have estimates of the biases of HYV wheat and rice vs local research, the HYVs had a positive impact on the demand for labor while local research had a negative effect. 2) Research was biased in favor of farm machinery and fertilizer. The suppliers of these commodities benefitted from research. Again, however, wheat and rice HYVs show a different pattern - demand for fertilizer increased but demand for machinery decreased. 3) Landowners and particularly larger landowners gained more income from new technology than small landowners or laborers. This is not due to the biases in the technology which is land saving but due to the initial distribution of land resources and the political process by which government supplied inputs are rationed.

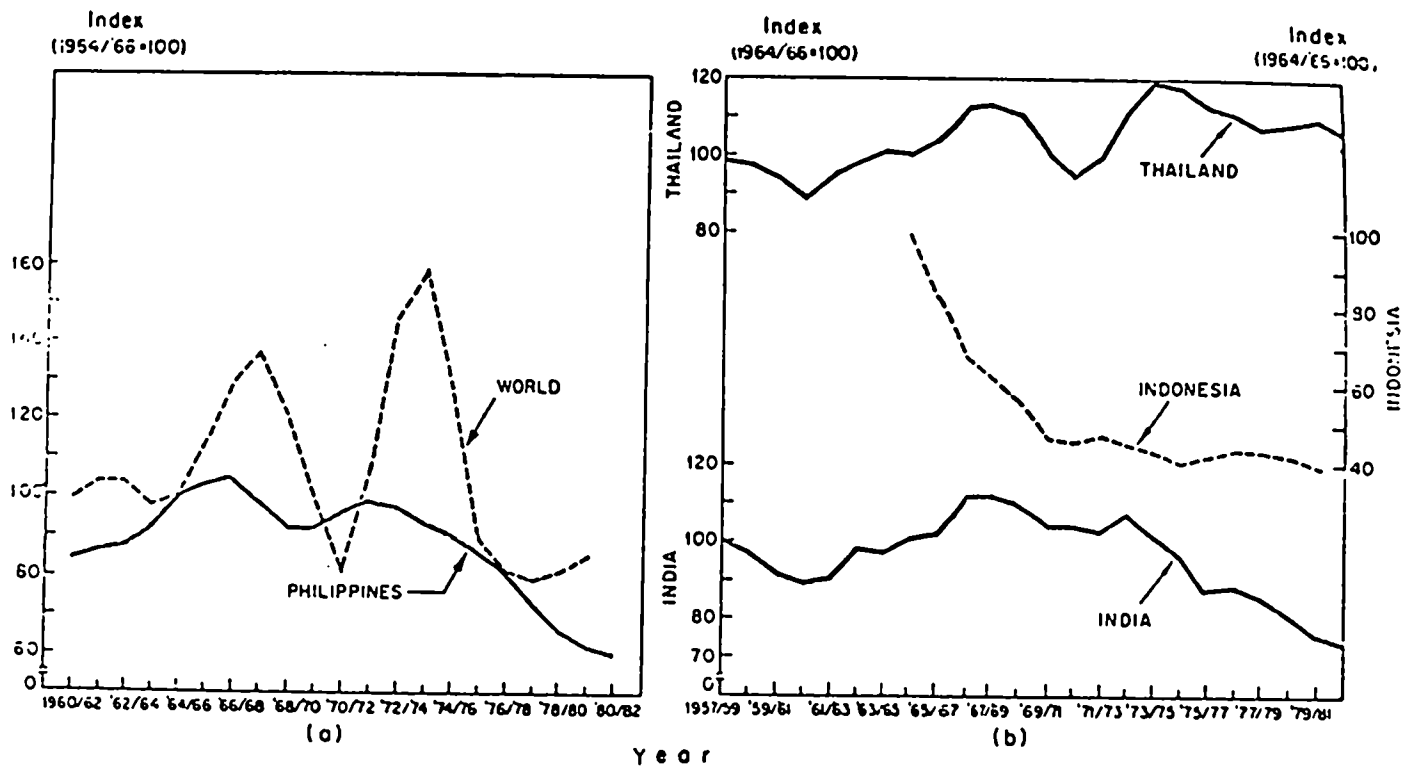
Impact of Research on Consumers and Producers

Research also affects income distribution through its effect on the output market. Research which increases yields per acre reduces the cost of production which pushes output prices down. Cost reductions will not push prices down if the crop is traded and is a small part of the world market or if the price is held up artificially by government policy. The elasticity of the demand curve and government policy will determine how benefits will be distributed between producers and consumers. The share of consumers' income which is used to purchase the agricultural product will determine the differential impact of the reduction in price on consumers. If research reduces the price of a commodity which is a larger share of the budgets of the poor consumers than rich consumers, the impact of research on income distribution will be positive. Food makes up 70 to 80 percent of the budgets of the poor in these countries and foodgrains are the major expenditure.

Although nominal prices of major foodgrains have risen in all six countries, the trends in real prices have been downward in recent years. Indices of real rice prices for the world and four of the countries from our study are presented in Figure 2.1. Real rice prices have also declined in Bangladesh (Pray and Ahmed, 1984). The real price of wheat which is the other major foodgrain of this region declined in India and Pakistan where it is most important. Figure 2.2 shows the declining prices of all foodgrains in India. Many factors have contributed to the decline in world prices of wheat and rice. One important factor has been the increase in output due to new rice and wheat technology in LDCs. Pinstrup-Andersen (1984) estimated that the increase in world output due to modern varieties was 10 million tons, or 5.4 percent of the total rice production, and 21 million tons, or 22.4 percent of total wheat production. This is enough to push prices down substantially.

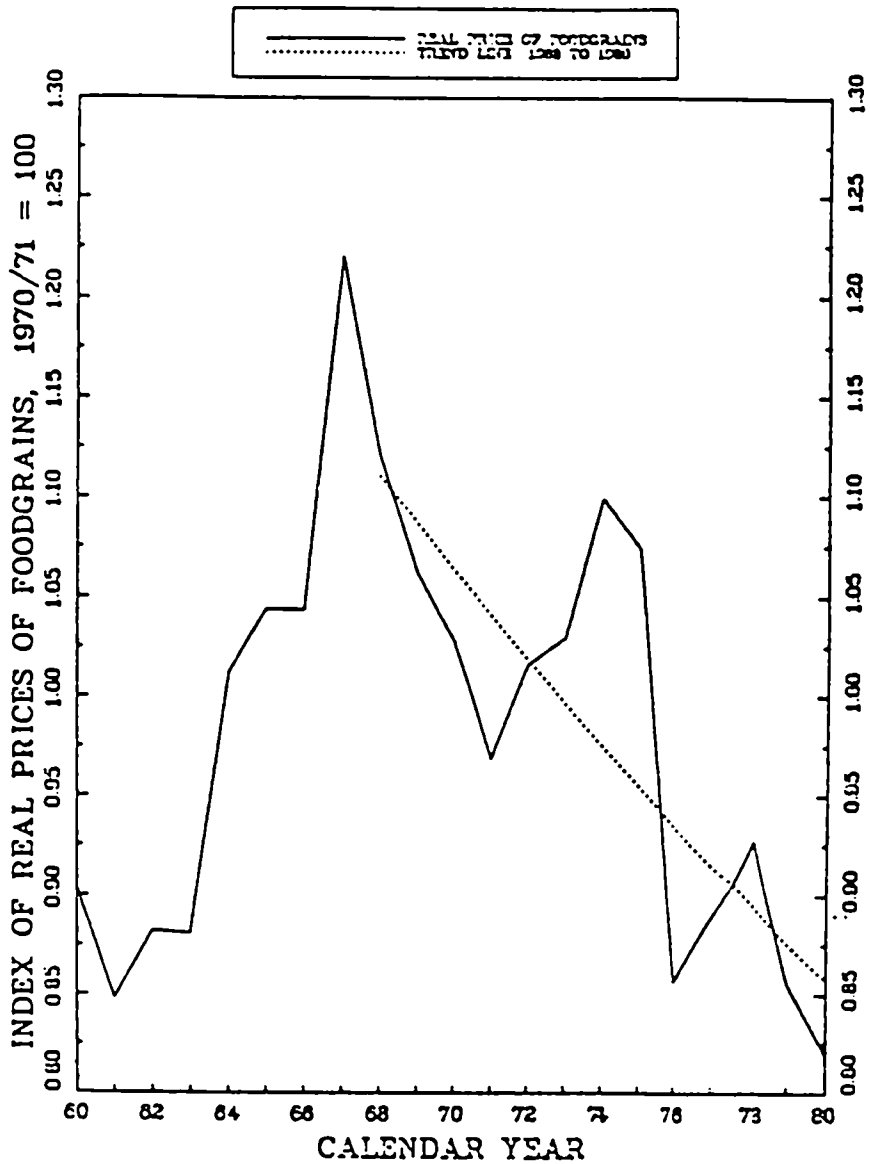
The distribution of the benefits from cost reducing technology in some countries is illustrated by the Bangladesh case. The main thrust of government policy has been to make up for shortages in foodgrain production by increasing imports of grain through commercial purchases or foodaid. In Figure 2.3 without the new technology Bangladesh would have had the supply curve S_o, have produced Q_o and have imported Q_2-Q_o. With the introduction of new varieties the supply curve is now S_1, local farmers produce Q_1 and imports are decreased to Q_2. This implies that the benefits of the new technology all went to farmers and area ABO is their increase in producer surplus. There has been a downward trend in the real price of rice in recent years. This may be due to the fact that the government has not reduced imports by as much as improved technology has increased output. Instead of importing Q_2-Q_1, the government imported $Q'_2-Q'_1$ and pushed prices down from P to P'. The market price and quantity will

Figure 2.1 Trends in Price of Rice at Constant Prices in Selected Countries.



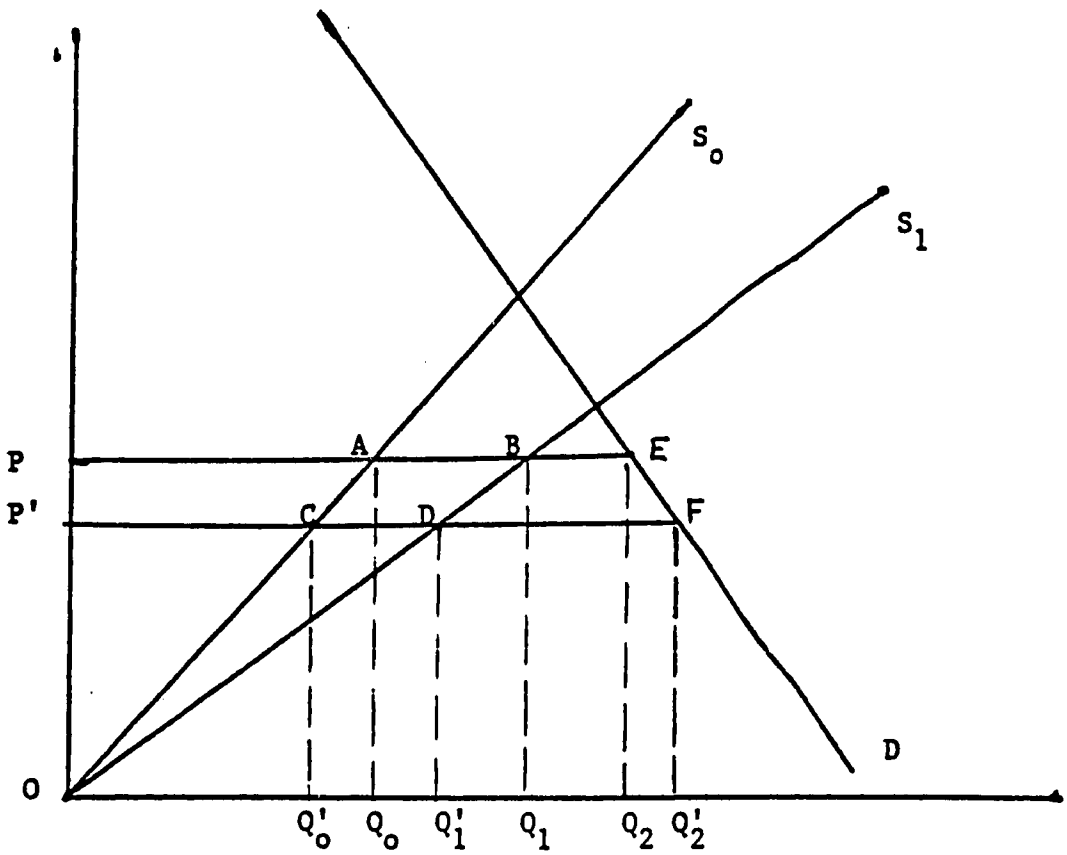
Source: Christina David, 1984.

Figure 2.2 Real Price of Foodgrains 1960-1980.



Source: Harrison and Wall 1981.

Figure 2.3. Bangladesh Foodgrain Market



be P' and Q'. The measured benefits to farmers will be CDO-ACPP'. The gain in consumers surplus, EFPP' was partially due to the new technology which cut the size of the budget outlay for foodaid which was needed to fill the gap between production and consumption and thus allowed the government to push prices down. It can also be attributed to the government policies themselves. The government was not forced by the new technology to continue large imports. In countries like Bangladesh where conditions fit this diagram consumers always gain and producers gain depend on the size of the price decline.

India appears to have followed policies similar to those of Bangladesh. It allowed grain prices to decline but provided price support by substantially decreasing imports and by exporting wheat in some years. Government price policies in the Philippines have been biased against the producers. In addition, the government was hesitant to export domestic surplus inthe late 1970s (David, 1984). This pushed prices down and allowed consumers to capture a large share of the economic surplus. Indonesia's policy concentrated on keeping consumer prices low. They increased foodgrain imports while new technology was increasing rice production (Herdt and Barker, 1985). As a result, much of the economic surplus due to new rice technology went to consumers.

The situation in Thailand and Pakistan was different from that in Indonesia. In Thailand research had a positive impact only on corn production. In the mid-1970's only 15 percent of corn output was consumed domestically (Collado, Drilon and Saguiguit, 1981) and Thailand had a relatively small share of the world corn market. Producers faced a very elastic demand curve and captured almost all of the gains from research. In Pakistan, Nagy's analysis (Nagy, 1984) assumes that the government only reduced imports enough to offset the increase in production. In this case also, all of the benefits went to the producers.

Quizon and Binswanger developed a general equilibrium model of the Indian agricultural sector. They used the producer core estimated by Evenson and Binswanger's previous studies, inputs supply equations, an output demand system and a model of migration. They then simulated the effect of various shocks to the systems under two different price and policy regimes.

The Quizon-Binswanger study shows the large differences that government price and export policies can make on the income distribution effects of technological change. Their model shows the percentage change in a variable 10 years after the system is shocked by a policy change. For example, column S4.1A in Table 2.3 shows that the impact of a 20 percent increase in rice yields in a closed economy is an increase in per capita income of 4 percent, an increase in total output of 8 percent, etc. The alternate columns designated S4.1B, S4.2B, etc. indicate the impact of policy changes on income distribution if all of the increase is exported. The impact on real per capita income of different income groups is also shown. Rural 1 and Urban 1 are the poorest quartiles of rural and urban families respectively.

In a closed economy the rice simulation indicates that increasing rice yields would have a positive impact on income distribution in the countryside. Incomes of Rural 1 would rise almost 7 percent. There would be almost no increase in the incomes of the wealthiest rural quartile. The biggest winners in this scenario would be the urban population. The incomes of urban quartiles 1 and 2 would increase by over 10 percent and urban 3 would increase by 9 percent. In an open economy all classes of rural population will increase their income with the high income groups gaining the most. All classes of the urban population would be worse off because rural resources are being drawn into rice production from other commodities. This would drive up the price of other commodities which they consume. The table indicates that the effect of increasing wheat yields on income distribution would be very similar to the rice case.

Table 2.3 Technical Change and Increased Export Scenarios

NAME	RICE YLDS+20% S4.1A	S4.1A_+ EXP+20% S4.1B	WHEAT YLDS+20% S4.2A	S4.2A_+ EXP+20% S4.2B	CEREAL YLDS+20% S4.3A	S4.3A_+ EXP+20% S4.3B	OTHER YLDS+20% S4.4A	S4.4A_+ EXP+20% S4.4B	ALL CROP YLDS+10% S4.5A	S4.5A_+ EXP+10% S4.5B
REAL NAT.PER CAP INCOME	4.158	6.4194	1.267	2.3755	0.760	2.7184	6.081	5.6052	6.109	8.5592
TOTAL OUTPUT	8.252	10.0088	2.309	2.6301	3.525	4.0232	5.219	5.6034	9.653	11.1327
Q OF RICE PRODUCED	20.312	27.8116	-1.789	-1.4805	2.895	0.5586	-0.719	-1.3123	10.349	12.7897
WHEAT PRODUCED	-4.854	0.5437	17.075	26.7489	1.489	1.3137	0.901	2.4075	7.306	15.5070
CEREALS PRODUCED	4.048	-4.4971	2.236	-2.2652	12.735	22.2588	-4.004	-6.6629	7.467	4.4168
OTHER CR PRODUCED	0.113	-1.7781	1.003	-0.2656	-0.145	-0.7606	21.265	24.2664	11.118	10.7311
GNP DEFLATOR	-8.941	5.8920	-7.063	2.1052	-4.212	3.5426	-12.506	5.1752	-16.361	8.3575
PRICES OF RICE	-26.846	3.5419	-10.002	3.9063	-1.130	8.1481	-10.223	10.7959	-24.101	13.1961
WHEAT	-15.603	12.1758	-32.438	-1.8577	-3.448	9.8176	-8.043	14.8548	-29.766	17.5453
COARSE CEREALS	-3.882	9.3248	-6.351	2.9885	-34.820	-9.1876	-16.932	4.4988	-30.992	3.8122
OTHER CROPS	-4.737	9.0456	-3.591	3.5978	-3.207	4.2925	-23.293	3.2681	-17.414	10.1020
REAL WAGE RATE	1.389	2.3440	-0.028	0.6481	-2.304	1.8801	0.314	-0.2733	-0.314	2.2995
LABOR EMPLOYMENT	1.116	0.8769	0.259	0.1968	-0.379	0.8247	0.224	-0.3630	0.610	0.7678
REAL WAGE BILL	2.505	3.2209	0.232	0.8450	-2.684	2.7048	0.538	-0.6362	0.296	3.0672
REAL RESIDUAL PROFITS	-3.203	33.4367	-9.027	12.5505	-1.919	14.8325	-0.899	32.7368	-7.574	46.7783
REAL PER CAP.INC.RURAL 1	6.725	2.9053	2.420	0.6014	3.691	2.3866	5.056	0.4587	8.946	3.1760
RURAL 2	4.893	7.0868	1.027	2.3932	1.522	3.4448	4.415	5.1696	5.979	9.0472
RURAL 3	3.969	9.8882	-0.079	3.5106	0.402	4.2071	4.074	8.3648	4.103	12.9854
RURAL 4	0.110	14.5595	-2.116	5.7442	-0.480	6.5220	2.746	14.2433	0.130	20.5345
URBAN 1	10.903	-6.1261	9.569	-1.8307	3.748	-3.5598	14.158	-6.5229	19.189	-9.0237
URBAN 2	11.367	-4.9817	7.238	-2.1715	1.605	-3.9069	13.672	-5.8396	16.941	-8.4799
URBAN 3	9.180	-4.7037	6.462	-1.8418	1.148	-3.4070	12.878	-4.9644	14.831	-7.4585
URBAN 4	4.656	-3.6614	3.485	-1.3953	0.095	-2.1166	11.276	-2.7179	9.756	-4.9457
PER CAP.CEREAL CONS.RURAL 1	10.532	3.1261	2.660	-0.0925	7.544	2.8111	0.166	-1.7990	10.451	2.0228
RURAL 4	4.715	6.1255	2.033	2.9603	-0.706	1.2103	-4.904	2.3552	0.929	6.1297
URBAN 1	11.948	-4.2200	11.519	-0.6872	5.917	-2.3249	6.313	-7.2253	17.848	-7.2327
URBAN 4	7.003	2.6916	1.194	0.0316	-1.298	-0.7404	-5.169	-2.0636	0.865	-0.0401
AGGREG.PER CAP.CER.CONS.	10.164	3.4895	4.076	0.6427	4.171	1.0453	-0.913	-1.2415	8.749	1.9680

Source: Quizon and Binswanger 1983.

Evenson believes that the closed economy model is probably the most appropriate for India. In a model of North India using many of the same variables he finds that the effect of investment in irrigation, local research and HYVs increases crop output and decreases prices. "Only the HYV effect actually increased the demand for labor and raised wages. Irrigation and research are substitutes for labor... However, by decreasing the price of output, the real wage can be increased," (Evenson, 1983: 35).

These simulations suggest that in India the effect of increasing rice and wheat yields will be to redistribute income to the rural poor and to the urban sector. This result however, depends heavily on the policy decisions of the Indian government. If it decides to increase exports or decrease imports by the same amount as the increase in output, the income distribution impact will be reversed - all urban groups lose, all rural groups gain, but the wealthy quartiles in the country gain more than the poor.

The Regional Distribution of Income

Table 1.2 showed that productivity growth was uneven in India. The same is true for other countries in our sample. Regions which do not experience productivity growth will be affected through the output and input markets. Productivity growth of a crop will depress the price which farmers receive for that crop. In regions where there was no productivity growth, net income from that crop will decline. This decline may be offset by price increases in other crops. For example, the prices of oilseeds and pulses in South Asia increased while prices of grain declined. The pulses and oilseeds are primarily grown in areas with poor soil and little water. Productivity increases work through the labor market to pull agricultural laborers into the areas of productivity growth. Punjab in India has pulled in a large number of laborers from nearby

states. It would be necessary to use a general equilibrium model to sort out the impact of different factors. Such a model has not been constructed. As a result we have reviewed the data available.

Research has been especially successful in producing new technology for regions where there is good water control but it has also had some success in unirrigated areas. This association between HYVs and irrigated areas has been noted in many studies. The spread on new wheat varieties, however, in Bangladesh has been primarily on unirrigated land. In Thailand improved corn is not irrigated. Improved rice varieties are spreading into areas of India and Bangladesh which are not irrigated but are well drained. Statistically the effect of research is positive and significant when irrigation is held constant. This shows that research has had an impact separate from irrigation. It is true, however, that the major impact of new technology in Asia has been in areas of good water control. This has led to a gain in income in these areas relative to less favored areas.

Is AID Making the "Right" Research Investments?

The early research projects funded by AID concentrated almost entirely on foodgrain production. The AID projects in India and Bangladesh helped build rice research capacity. AID helped fund CIMMYT and IRRI research on rice, wheat, maize, barley and triticale. The first Pakistan research project strengthened the Agricultural Research Council which primarily funded research on foodgrains. The Thai project was the most diversified, dealing with all crops grown in the northeast. The Asia Bureau continues to provide resources for foodgrain research but has recently included some other important subsistence crops like pulses and oilseeds.

We divided the research support by AID Asia Bureau into commodity groups. We used six broad categories of commodities: major foodgrains; minor foodgrains, pulses, oilseeds, and rootcrops; nonfood crops; animal products; fish; and forest products. Our assumptions in constructing these categories were: first, research on irrigation is allocated to major foodgrains; second, rainfed areas research projects primarily benefitted the minor foodgrains, pulses, oilseeds and root crops; and third, half of farming systems research went for major foodgrains and half went to minor foodgrains. At present, major foodgrains account for roughly half of the expenditure, other foodcrops almost 40 percent, and the rest is split between forests and fish. Nonfood crops and animal agriculture appear to receive nothing. This is an exaggeration because some nonfood crops such as cotton are undoubtedly affected by the irrigation research and farming systems research projects in some countries. Likewise, some of the work on forest products includes research on forages and range management. Some farming systems and irrigation management projects examine fodder production. It is clear from an examination of these projects that nonfood crops and animal production do have the least research resources.

The trend in commodity priorities is to gradually de-emphasize the major foodgrains. More emphasis is being placed on pulses, oilseeds and rootcrops. There is increasing interest in forest management and agroforestry in South Asia and in fisheries in Southeast Asia. In most countries the benefits from oilseed research will go to farmers and processors because the countries which do research on this crop are primarily importers at present. Research on millets and pulses will be divided between consumers and producers with poor consumers receiving most benefits.

In addition, AID is trying to focus research projects more directly on the small farmer through the farming systems framework. Although this type of

research is still evolving, it is clear that farming systems research does provide researchers with more contact with small farmers than they had in the past. If scientists listen to the small farmer and revise their research priorities to meet his needs, farming systems will help the small farmer.

Increased food production is the main goal of the agricultural policies which AID and the World Bank promote. They have argued fairly consistently against subsidizing urban consumers through policies that hold down the price of foodgrains and other agricultural commodities. At the same time they have argued that input subsidies should be eliminated. The governments of the six countries in this study have different policies. The same policy prescription will not have the same result everywhere. In order to understand the full impact of a policy on income distribution, itis necessary to have a general equilibrium model which includes how the government uses the money it saves through reduced subsidies. Even without this model it appears that the current agricultural policies promoted by AID generally improve income distribution. Increased prices for agricultural commodities will shift resources to the countryside. Reducing input subsidies will in many countries mean that inputs are no longer rationed on the basis of political power but are rationed by the marketplace. This should increase the access of small farmers who have little political power to modern inputs.

Chapter 2

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Chapter 3 Determinants of Research Expenditure

A Model of Technical Change

To understand the determinants of research expenditure it is necessary to have a model of the supply and demand for new technology. Agricultural research is one of several ways in which the demand for new agricultural technology can be met. The model presented below is based on the induced innovation models of Hayami and Kuttan (1985).

The demand for new technology is based on the perception of individuals or firms that they can improve their income, profits, or welfare from new technology in the agricultural sector. These individuals and firms can be divided into four broad groups: 1) farmers, 2) suppliers of inputs, 3) merchants and processors, and 4) consumers. Farmers who are producing commodities which have elastic demand curves or who are early adopters of new technology for all commodities can increase their income by adopting new technologies which reduce cost. Input supply firms can increase their profits by introducing new and improved inputs which cost less to produce or for which they can charge farmers more or can sell higher volumes. Merchants may increase their profits through agricultural technology which increases the quality of a commodity and in turn opens new markets. Technology that decreases farmers' costs of production can provide benefits to processors by reducing the cost of their inputs and to consumers by reducing the cost of their food and fiber.

This ability to improve income, profits or welfare through new technology will be referred to as latent demand for research. Latent demand does not become actual demand for research unless these groups believe that research is a way of obtaining the technology which they need and they also have the political or economic resources that are necessary to make this demand effective.

The demand for research requires knowledge about what research can do and an assessment of expected costs and benefits from research vs. other possible means of solving problems. Individuals or firms must choose between (1) doing research or importing technology themselves, (2) organizing groups which finance research and/or the import of technology or (3) putting political pressure on the government to do research or import technology.

If a firm feels that it can capture enough of the benefits from research both to cover its costs and the risk premium it requires because the research might fail to produce the desired results, it will invest in research. The benefits that any individual or single company can expect from research are rarely as large as the total social benefit which society receives from agricultural research. The results of research even if they are embodied in an input are easily transferred between farms and few farmers or companies are big enough to capture a major share of the benefits. Often the expected benefits an individual farm or firm can capture are less than the cost of doing research. The benefits may not be sufficient even to justify the costs of searching for new technology that has been invented elsewhere in the world. Therefore, in the absence of collective action by firms or of government intervention, individual firms will not produce the socially optimal level of research and new technology.

When individuals and firms see that they cannot profit by individual action, they may turn to collective action. Collective action implies an institutional change of some type. In many cases farmers have organized commodity groups to finance research. In other cases groups organized for other purposes have started to do research. The members of these groups tax themselves to finance improvements which will benefit all growers of the commodity. The other alternative is to influence the government to start a new research program using

general revenue or to influence current research programs to work on the problem. This also usually involves group action to lobby the government for the needed change.

The decision of individuals and firms about which alternative to choose will depend on the expected cost of developing new technology in old institutions and the cost of organizing new institutions. The cost to these individuals and firms will be not only the financial cost of establishing a research program, but also the financial and transactions costs involved in lobbying the government or establishing a new commodity organization.

There are a number of economic and political factors that can shift the demand for new agricultural technology and thus for research. These factors can also shift the composition of the innovations that are demanded. These factors include changes in 1) knowledge about what research can do, 2) the nature of agricultural problems that become important, 3) the demand for certain commodities, 4) the prices of agricultural inputs, 5) laws such as patents and regulations, and 6) the role of government in agricultural production, input supply and marketing processing and consuming agricultural commodities.

Four general types of institutions or individuals supply new agricultural technology in Asia. These are 1) government institutions, 2) companies and individual firms, 3) commodity organizations and cooperatives, and 4) foundations, nongovernment organizations (NGO's) and nonprofit research centers.

The incentives for these institutions to provide new technology are somewhat crudely summarized as follows. 1) Governments get reelected or hold on to power if they can meet the demands of people for cheaper food, greater economic growth or political goals like self-sufficiency and more exports which may or may not be economically justified. Governments may also invest simply because their constituents feel science and technology is modern. 2) Private

firms invest in research if they can increase their profits by supplying new technology. 3) Commodity organizations or coops invest in research to increase the profits and income of their members. 4) NGO's and foundations increase the personal satisfaction of their members by transferring technology.

A number of factors can shift the supply or the composition of new technology supplied. Factors that reduce the cost of the inputs for the research process shift the supply of technology from both public and private research institutions. These include reducing the cost or increasing the supply of trained manpower through building agricultural universities and sending students for training abroad, reducing the cost of physical capital through foreign aid, and reducing the cost of scientific information through building international research centers. Breakthroughs in basic science or in the methodology of applied science can shift the supply curve of technology outward. Applied science without breakthroughs in more basic science will run into diminishing returns which increase the cost of research. Political changes can change the cost of inputs and also change the efficiency with which inputs are used to generate new technology.

Quantitative Evidence

Judd et al (1983) tested most of the major determinants of government research expenditure which were in the model described previously. Accurate data on private research expenditure are not available in most countries. This should not bias the results for the LDC's because private research makes only a small portion of total research expenditure in most LDC's. In India it was calculated to be less than 10 percent of all agricultural research expenditure (Govt. of India); in the Philippines it was less than that (Boyce, 1980). Judd et al used a data set which included the four major commodity groups in 26

developing countries of Asia and Africa during the 1970's. They also estimated the determinants of growth in total government agricultural research from 1959 to 1980 using a second set of data including over 80 developing countries in Asia, Africa and Latin America.

A list of variables, the estimates of the determinants of commodity expenditure on research from the 26 developing countries and the estimates of the determinants total research expenditure are presented in Tables 3.1, 3.2, and 3.3 respectively.

The variables which determine the demand for research include value of output, value of exports, value of imports, availability of land, fertilizer/rice price ratio, and research which is going on the same crops or in similar agroclimatic zones. Extension could have been included as a determinant of research since more extension and education should mean more demand for research. The supply side variables include the cost of scientists, research at the international centers and other research in the same agro-climatic zone.

The functional form used in their analysis was:

$$LN(Y_i) = D_c + D_s D_t + \alpha_1 LN(PROD) + \alpha_2 LN(PROD)(XPORT) + \alpha_3 LN(PROD)(MPORT) + \alpha_4 LN(PROD)(CROPSH) + \alpha_5 ARABLE + \alpha_6 LN(REPRICE) + \alpha_7 LN(NATSR) + \sum_{k=8}^{k=14} \alpha_k X_k$$

Several of the demand side variables were positive and significant determinants of research expenditure. The value of imports was an important positive factor in determining research expenditure on staple foods in the commodity data set (Table 3.2). In the country level data (Table 3.3), imports had a positive and significant relationship to research expenditure. Judd interprets this as evidence of the importance of cheap foodgrains in government decision-making. The

Table 3.1 Determinants of Research Expenditure: Variables Dictionary and Means

Variables	Commodities Data Base 26 Countries	General Data: 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	30197.04
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
Transferred Related						
X_7: NATSR: (SMY's devoted to research in similar regions in other countries)	8.66*	5971.66	6082.86	7852.81	17875.43	20811.02
X_8: INTSR: (Expenditures in millions 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)	56.45	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.

*millions of 1980 dollars devoted to research in similar regions in other countries.

Table 3.2

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

Dependent Variable: LN(RESEXP)

	Pooled Samples					
Independent Variables	Cereal Grains	Staple Foods	Cash Crops	Tree Crops	Livestock	All
LN(PROD) (α_1)	.354 (13.22)	.162 (8.71)	.119 (4.94)	.089 (2.86)	.083 (3.46)	.157 (15.10)
LN(XPORT) (α_2)	.0164 (.45)	.0953 (2.78)	.1314 (3.99)	.257 (6.32)	.148 (3.93)	.131 (8.43)
LN(MPORT) (α_3)	.00296 (.08)	.1389 (3.29)	.014 (.45)	.025 (.57)	.0004 (.01)	.032 (1.90)
ARABLE (α_5)	-1.249 (1.27)	-.093 (.13)	-.699 (.82)	-1.597 (1.94)	-3.078 (3.77)	-1.419 (3.70)
LN(REPRICE) (α_6)	.418 (2.78)	.295 (2.79)	.304 (2.42)	.483 (3.95)	.656 (5.46)	.455 (8.04)
LN(NATSR) (α_7)	.0856 (1.42)	.0704 (1.50)	.1039 (1.82)	.080 (1.54)	-.051 (.95)	.060 (2.55)
INTSP (α_9)	.147 (.30)	-.346 (.42)	na	na	.203 (2.91)	.189 (2.83)
INTLOC (α_{10})	.323 (.65)	1.571 (4.34)	na	na	-.266 (.43)	.948 (3.43)
INTLOC(YR)	-.007 (.33)	.060 (.76)	na	na	.0016 (.11)	-.007 (1.26)
ECONAG (α_{11})	-.0149 (.91)	-.0171 (1.35)	-.031 (2.02)	.002 (.12)	.041 (2.93)	-.007 (1.01)
URBANIZATION (α_{12})	.0024 (.16)	-.0036 (.32)	-.0154 (1.18)	.004 (.29)	.026 (2.12)	.0001 (.02)
INSTABILITY (α_{13})	-772.6 (.88)	39.5 (.06)	105.05 (.13)	1443.5 (1.89)	246.2 (.33)	201.9 (.57)
FERTRICEPR (α_{14})	.056 (.72)	-.030 (.57)	-.037 (.57)	-.050 (.78)	-.147 (2.24)	-.045 (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
Quantity Price Elasticity	-.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/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 3.3

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	-2.95	-2.64	-1.09	-.91	-1.09	-5.28
Y_2	-2.15	-2.14	-.83	-.71	-.90	-4.01
Y_3	-1.59	-1.74	-.55	-.52	-.62	-3.38
Y_4	-1.01	-1.41	-.29	-.35	-.43	-2.51
Y_5	-.82	-1.16	-.14	-.23	-.39	-1.59
Y_6	-.71	-.93	-.16	-.24	-.25	-.93
Y_7	-.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
Price Elasticity	-.884	-.664	-1.006	-.842	-.728	-.260

coefficient of the value of exports is larger than on imports and highly significant in the commodity based estimates. However, in the country data, increases in exports did not have strong impact on total research expenditure of low income countries.

This supports the observation that even in the 1970s, research budgets in developing countries were responsive to changes in the value of export crops. However, low income countries respond more rapidly to changes in imports than to changes in exports. Judd et al also estimated the elasticity of research expenditure with respect to the commodity's share of production in the commodity data set. They found that the elasticity was positive but low. This shows research expenditure does respond positively to increases in the value of output but suggests there are strong economies of scale in research.

Another demand side variable with considerable explanatory power in both the commodity and the country based data sets was the arable land variable. This was defined as the ratio of current arable land to arable land six years previously and was a proxy for the availability of land. It was negatively related to research expenditure in both sets of data which indicates that when arable land is readily available, countries invest less in research which will increase yield per acre. This variable determines the means by which the private sector fulfills the demand for less imports, more exports or cheaper food. When land is readily available, supply can expand easily with little increase in prices and there is little pressure on the governments to invest in research.

Several of the supply side variables were also significant. Research expenditure of low-income countries is positively related to the expenditures of International Agricultural Research Centers which are dealing with similar regions and crops. National research expenditure is negatively related to research expenditure of other countries in similar agroclimatic regions. The

first part supports the theory that shifts in the supply of innovation due to the IARC's research induce research investment by national systems. The second part suggests there are important spillover effects and some tendency toward free riding.

Judd et al also included a variable to reflect the cost of research REPRICE. This is the ratio of research expenditures per scientist to extension expenditures per extension worker. This variable is highly significant in the commodity data set. The estimate indicates a real elasticity of research expenditure with respect to price of research of -.55. "A ten percent reduction in the price of research will lead to an increase in the quantity purchased of 5.5 percent" (Judd et al, 1983: 41).

Evenson and McKinsey (1983) tested whether these same factors also determined Indian research expenditure. They used state level data for the period 1959-75. They found that the coefficients of literacy, research in neighboring states, availability of agricultural college graduates, past extension activity and state commodity production were positive and statistically significant determinants of research investment. Road infrastructure and credit institutions were also positively related to research. The import of HYVs of wheat and rice varieties and urbanization had a negative and significant effect while the level of state revenue had no effect on research.

Otsuka (1980) tested the relationship between rice and wheat prices and research output measured by publications about rice and wheat. He used Indian state level data. His model of research output suggested that research should be a function of the benefits of research to farmers and that a major factor determining financial benefit was the price of the product. Prices varied in different states because of government policies. His regression results indicated that

rice research output is positively related to rice prices, the cost of irrigation, total rice cropped area, and past state research expenditure. The wheat price coefficient is positive but not significant in explaining wheat research output. The only variable that is significantly related to output is wheat research expenditure which is positive as expected.

Qualitative Evidence

The quantitative studies are useful in identifying factors that determine research expenditure, but they do not explain why there is still underinvestment in agricultural research and why research resource allocation is skewed toward certain crops and not others. This section attempts a partial answer to these questions.

All country studies in our project showed rates of return to research far higher than the cost of capital and far higher than those calculated for most public sector projects. In recent years research expenditures in Indonesia, Bangladesh and Pakistan have been growing very rapidly. In 1980, however, all of these countries spent less than 0.5 percent of their agricultural GDP on agricultural research and the Philippines spent only .16 (see Table 1.3). In the Oram and Bindlish (1981) study the average percentage expenditure for the entire sample of 51 developing countries was .56 percent. These figures show that there still is underinvestment in agricultural research in those countries. Even these figures exaggerate the local commitment to research because a large portion of these countries' budgets are met by donors.

The distribution of research resources between commodities is uneven. From the time formal research in South and Southeast Asia started until about 1960 export crops received a far larger share of research resources than their value to the economy as a whole warrented. In all of these countries, some research

on basic foodgrains was conducted. There is evidence, however, to support the underinvestment in foodgrains relative to export crops from data on numbers of publications (Boyce and Evenson, 1975; Pray, 1982) or the allocation of scientists (Pray, 1978 and 1984).

At present research resources are allocated in an apparently skewed manner across commodities. Table 3.4 shows the ratios of research expenditures to the value of commodity for four of the case study countries. A rough rule of thumb is that these ratios should be about equal. If they are way out of line, there should be a very good reason for it. In many cases there is a good reason, but at least some questions should be asked. This table shows that in each country these ratios are very skewed. In general rice which is a major foodgrain in these countries has the smallest ratio. In three of the countries cotton has a very high ratio. In Indonesia cattle research has the highest ratio.

This table confirms some general trends which our team found in country visits. First, although the share of research resources that is used for major foodgrains has increased greatly in recent years, it rarely comes close to the share of those crops in agricultural GDP. Second, "poor peoples' crops" like sweet potato and cassava have received little attention anywhere in the world. Third, a sizeable amount of government research money has been spent recently on minor crops such as wheat and soybeans in the Philippines or soybeans and corn in Bangladesh. These crops have little chance of becoming important crops.

As the examples will indicate, demand for research is usually demand for commodity specific research. Less frequently there is demand for research on a regional problem such as salinity, nutrient deficiencies or pests. In some countries the demand for government research is based on goals of the society as

Table 3.4 Comparison of Research Intensities of Thailand, Bangladesh, Philippines and Indonesia.

Commodities	Thailand (1979)	Bangladesh (1975-80)	Philippines (1980)	Indonesia (1978)
Rice	.0016	.0008	.0003	.0005
Corn and Sorghum	.0053	.0147[c]	.0013	
Corn	.0065		.00095	.0013
Sugarcane	.0014	.0039	.00011	
Cassava	.0015		.00541	.0008[d]
Soybean	.0017[a]	.0091[a]	.01280	
Fibre crops	.0177	.0035	.00990	
Cotton	.0498	.0155[e]	(high)	
Vegetables	.0026		.00430	
Fruits	.0005	.0032	.00087	
Tobacco	.0006		.00590	
Rubber	.0054		.00130	
Cattle	.0014[b]		.00080	.0080[b]

Notes: a Using oil crops research intensity.
b Using livestocks intensity.
c Corn, sorghum and wheat.
d Cassavia and soybeans.
e Cotton and tobacco.

Sources: 1) Thailand, Rungruang 1981.
2) Bangladesh, Pray and Ahmed.
3) Philippines, Evenson et al 1982.
4) Indonesia, Salmon 1984.

a whole such as the idea that science is the road to development, that agricultural science can fight hunger or keep the country competitive in international markets. The total demand for research is the sum of all of these types of demand. In the following analysis I will first examine the factors which determine the allocation of resources and then build on that to analyze aggregate demand for research.

Growth in Export and Cash Crop Research

The early growth of agricultural research in Asia was led by the demand for research on a number of export commodities. The reduced cost of transport during the second half of the 19th century greatly increased the European demand for Asian agricultural commodities. The supply of many of these commodities expanded rapidly by increasing the amount of acreage under production. However, some commodities could not respond as rapidly as hoped either because of input constraints or the quality of the commodity did not match European standards.

In the beginning the demand for research existed primarily among small groups of Europeans who (1) were in positions to profit from expanded demand for exports, (2) knew what science could do for agriculture and (3) had the means to pay for research or lobby the colonial administration for government expenditure. For example, the first commodity research program in Asia was the Proefstatien Oost Java. It was established by Dutch sugar producers in 1885 in response to a disastrous virus disease attack on the 1883-84 sugarcane crop in Java.

In India industry associations hired scientists to look at specific agricultural issues in the late nineteenth century. Tea producers in India faced a number of problems in the 1890's. They wanted to know whether oilcakes and other fertilizers increased the output of their crop. They were also interested

in the factors that determined the quality of tea and how to control insect pests that affected production in some areas. They hired scientists to investigate these problems and they used their influence with the government to try to get public financing for their research programs (Griffiths, 1967).

At the beginning of the twentieth century expanded exports of jute and cotton from India were constrained by quality problems. The price of jute which was being exported from eastern India was declining and jute merchants felt this was due to a decline in the quality of jute (Finlow, 1921). The British cotton industry wanted longer staple cotton to replace American imports. Merchants and industrialists lobbied the governments of Great Britian and India for scientific research to overcome quality constraint problems (Pray, 1983). To justify a full scale government research system these special interests needed to show that research would benefit more than just the narrow interest groups. It was not until the famines that the Government of British India was able to justify establishing a Department of Agriculture for all of India.

On the supply side several breakthroughs in science increased the output of research. First, Mendel's laws of genetics were rediscovered, which made plant breeding more scientific and hence more productive. Second, the method of sexually crossing sugarcane was discovered in Indonesia. This allowed sugarcane scientists to make dramatic improvements in yield per acre. This technique spread rapidly through sugarcane growing areas of Asia, Africa and the Americas.

After Independence the demand for research on export crops and other cash crops continued to be strong. The producers of these crops were usually the best organized and wealthiest farmers. One exception is Indonesia where the export crops had been controlled by the Dutch who left at Independence and were not replaced by an indigenous planter class. The demands for research in Asia were supported by the industrialists who needed cheap raw materials for their

industries and foreign exchange from exports to buy equipment and technology. The general policy of supporting cash and export crops was encouraged by government officials and intellectuals who believed in modernization through industrialization.

The result was a continuing bias toward export and cash crops after Independence. In Pakistan cotton received a far larger share of research resources than warranted by its importance in the economy through the 1960's (Pray, 1983). The region that is now Bangladesh invested heavily in jute research (Pray and Ahmed, 1983). India invested in cash crops like cotton, sugarcane, and tobacco. Thailand invested in research on corn for export. The Thai research on rice was aimed at improving quality for export markets rather than increasing yields (IRRI, 1970). There were large investments in Philippine research programs on export crops like sugarcane, coconuts and tobacco (Lantican, 1971).

In recent years some changes in the supply and demand of technology have reduced the demand for research on export crops in some countries. In many countries, governments nationalized the companies which process these crops. These companies frequently became inefficient, lost part of their market share in the world market, and became increasingly unprofitable. In that condition they had little cash or incentive to invest money or political capital in agricultural research. In India some of the better organized commodity groups lost control over their research programs and in the process also lost interest in the research.

Growth in Foodgrain Research

In both the colonial period and after Independence the demand for cost-reducing technology and cheap food has been an important source of demand for

government research. Research on foodgrains started during the colonial period in Asia. The establishment of the Indian agricultural research system was one of several reactions to the series of famines in British India which occurred during the last 20 years of the 19th C. The British wanted more food for both humanitarian reasons and to ensure political stability of their colony. In Malaysia the interests of local consumers were represented by plantation owners who wanted inexpensive food so they could keep wages down. A sharp increase in rice prices around 1920 prompted them to push for rice research and irrigation. The 1918 rice riots in Japan led the Japanese government to invest in ri e research in Taiwan and Korea (Hayami and Ruttan, 1985).

Since Independence, rapid population growth and in some countries increasing per capita incomes have greatly increased the demand for grain. At first this increased demand was satisfied by bringing more land into cultivation or importing grain. By the 1960s in some countries no more land was available and bad weather caused price increases in most basic grains and acute food shortage. These factors led to the rapid growth of foodgrain research during the late 1960's and the 1970's.

A recent example of the way food prices induce research is the case of pulses in South Asia. In the last three years the price of pulses which are a staple in most South Asian diets has gone up rapidly in Bangladesh and Pakistan. In Pakistan at the end of 1981 the shortage of chickpeas was severe because the crop had been attacked by disease three years in a row. These shortages led to protests and near riots in several northern cities. This led President Zia to give orders for the Pakistan Agricultural Research Council to solve this problem. In response the Council has shifted manpower and financial resources to pulse diseases. In Bangladesh the basic problem was a drought year followed by a year in which freak rains in the Spring washed out many acres of pulses.

The shortage was also due in part to increased wheat production in areas which traditionally grew pulses. The result of these shortages has been an increase in government support for pulse research and a demand for improved varieties of pulses.

Imports of agricultural products have stimulated demand for agricultural research in several ways. Imports have been a major drain on foreign exchange and as such acted as a constraint on the growth of other sectors of the economy. In the 1970's commercial purchases of foodgrains were an important drain on the foreign exchange reserves in most Asian countries with the exception of Thailand. In the 1980's food imports continued to drain foreign exchange in several countries. In India and Pakistan, imports of vegetable oil and oilseeds surpassed foodgrains as a major commercial import. In these countries this led to an increase in the resources devoted to oilseed research.

In some cases U.S. foodaid has reduced this drain of foreign exchange reserves. All of these countries but Thailand have been major recipients and several continue to receive foodaid. Difficulties in getting foodaid on time and political costs involved led these countries to emphasize self-sufficiency in foodgrains. There are several examples of the costs of foodgrain dependence in South Asia. The U.S. stopped shipments to India and Pakistan during the 1965 war and then threatened to cut off AID to India if it did not agree to certain internal agricultural policies (Subramanian, 1979). In 1974 foodaid to Bangladesh was delayed during a famine year and the Bangladeshis believe this was an attempt by the U.S. to force them to break their trade relations with Cuba (Sobhan, 1979). These types of events motivated the governments to invest more in research in order to become more self-sufficient.

The supply of foodgrain technology shifted outward dramatically through advances in science and scientific methodology in the 1960s. The best example

of this was the identification of the dwarfing genes that made possible the fertiiizer responsive wheat and rice varieties of the Green Revolution. Increased communications between scientists due to the IARC, which allow these and many less dramatic advances in science to move across institutional and political boundaries, can also increase the supply of new technology.

The Green Revolution and the publicity which accompanied it showed bureaucrats and politicians that foodgrain research could be an important source of growth and generated considerable demand for research both in Asia and in the donor community. A number of research institutions were able to capitalize on this demand by increasing their budgets substantially. In some countries, however, the pace of agricultural growth has been disappointing because there was the expectation of continuous and dramatic innovations which would lead to rapid growth. A problem for local scientists in Bangladesh, Pakistan and perhaps elsewhere is that politicians and bureaucrats believe the breakthroughs of the Green Revolution were primarily due to IARC research and that the local system has not produced anything useful. A more serious long-run problem is that the farmers who are benefitting from the new technology may not know that the technologies they use are from the local research system. Their sources of information about the new technologies are their neighbors, the extension system or input suppliers. These groups may have no incentive to tell farmers the source of the new technology. Even if farmers do know where the technology comes from, they may not have sufficient p r to turn this latent demand into actual demand for larger research budgets.

The lack of grass roots demand seems to be the most important constraint which prevents research institutions from optimizing their budgets for foodgrains at present. Although some farmers have benefitted, it has been politicians reacting to consumer crises rather than farmer needs who have demanded

research. This is particularly true at present when donors seem willing to invest substantial amounts to provide facilities. As a result, politicians do not have to raise taxes and local systems do not have to build up their constituency.

Private sector research on foodgrains responded somewhat later than the public sector. The 1970s was the first time that there was sufficient demand for marketed inputs to justify a sustained research program on Asian problems by private input supply companies. Hybrid corn research projects were set up by San Miguel Corporation in the Philippines and DeKalb in India in the 1950s and 1960s. However, sustained research programs on hybrid crops by private companies did not start until the 1970s when Pioneer, Cargill, Pacific Seeds, DeKalb, San Miguel, CP and local Indian companies started doing research in Thailand, the Philippines and India.

The seed research programs of the 1970s were induced by several factors. First, the private market for high quality seeds has increased in each country. The success of modern wheat and rice varieties greatly increased the number of farmers who purchased seed outside their village. Second, several specific government programs have subsidized the purchase of hybrid corn seed. Third, the government reduced its role in seed distribution in several countries and in some countries removed laws that prevented private companies from doing plant breeding. Fourth, corn varieties with resistance to downy mildew and chemical seed treatment for downy mildew were developed. This disease had been one of the main constraints to the spread of corn hybrids in Southeast Asia. Finally, the availability of well-trained but underpaid government scientists who were willing to work for the private companies has increased the expected payoff from this investment.

Trials of chemical fertilizer and pesticides by private companies started before World War II in most Asian countries. Companies were aiming at the plan-

tation crops, but they also did fertilizer trials on foodgrains in India. After Independence chemical companies continued to concentrate on the plantation sector and a few cash crops like cotton which required large quantities of insecticides. The Green Revolution induced a major expansion in research and development activities by chemical companies on Asian foodgrains. This was in part due to the responsiveness of the modern wheat and rice varieties to fertilizer and of modern rice varieties to pesticides. Government subsidies of fertilizer and agricultural chemicals and in some cases free application of pesticides by the government increased the size of the market for fertilizers and agricultural chemicals. In recent years governments in several of these countries have reduced their role as a supplier of agricultural inputs. This has enabled private companies to expand their share of the market.

Expanded demand for agricultural chemicals has induced many companies to increase their research and development activities. A number of multinational chemical companies do research in India. The Indian government requires research if a foreign company wants to do business there. Union Carbide develops new compounds in India which it then ships around the world for testing. ICI Industries has a research farm in India to test pesticides for India and surrounding countries. Ciba-Geigy has an experiment station for tropical pests in Indonesia and American Cyanimid does tropical pest trials at Los Banos in the Philippines. A number of American and European firms do research on rice pesticides in Japan and then transfer this technology to tropical Asia.

Other factors had a negative impact on research by chemical companies. The lack of an effective patent system for pesticides in Thailand and Indonesia and what foreign companies see as a deterioration of the patent system in India have slowed the growth of private research and development activities in those

countries.[1/] The Union Carbide disaster in Bhopal will certainly slow the growth of investment by the pesticide industry in Asia at least temporarily and research with it.

Research Allocation and Underinvestment

The description of the forces which caused the expansion of research expenditure in foodgrains and export crops suggest several reasons why more research resources have been invested in export and cash crops. First, expenditure on foodgrain research makes major gains when there is a foodgrain crisis that threatens to destabilize the elite and their government but does not grow much when there is no crisis. This has often been the case in both the colonial period and after Independence. Second, the government is more interested in foodgrain research if foodgrain expenditures are a major drain on foreign exchange. Third, private companies did not start research on foodgrain until the last few years. They continue to underinvest because of government constraints on their profits and their inability to capture a major share of the gains from research. Finally, shifts in the supply of technology if well publicized to the elite may also induce increased investment in agricultural research but if results do not show up quickly the elite loses interest.

In contrast, the growth in research on export crops has been led by small, well-organized interest groups such as tea planters' associations and the Indian Jute Mills Association. They either tax themselves, persuade the government to set up earmarked taxes for research, or convince the government to fund research out of general revenues. They have continued to lobby effectively for government research in several countries. The skewed distribution of research resources

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1/ See Evenson, Putnam and Evenson (1983) for a detailed discussion of patents and other types of property rights in the Third World.

appears to reflect the ability of small, well-organized producer and processor groups to do sustained lobbying for the commodities in which they are interested. Foodgrains do not have this type of lobby. Farmers have very little political influence in most of these countries.

The overinvestment in some of the minor crops is supply driven. Scientists, both expatriots and locals, have decided that a certain crop is the way to make a name for themselves and have pushed these crops hard. They have been able to team up with donors who have special interest or expertise in this crop. They also receive the support from officials who are concerned about foreign exchange and self-sufficiency because wheat and cooking oils are frequently big import items.

In addition to the factors just discussed several demand and supply factors which cut across all commodities were important causes of underinvestment. In the 1950's the demand for research was relatively weak due to the perception that research was not a very productive investment. The research systems in all six countries except Thailand went through an unproductive period after Independence due to supply side constraints. They had to replace colonial scientists, replace facilities damaged by the war or lost at Independence and build new linkages to the world science community. In the 1940's, Indonesia lost all the well-trained scientists in the public sector and most of the scientists in the private sector because they were all Dutch. Some of them returned in the 1950's but left for good around 1960 (Boyce, 1960:14). Bangladesh and Pakistan lost a few British scientists but their main loss was of Hindus and Sikhs to India in 1947 (Pray, 1983). India lost a few British scientists, some Muslim scientists and several important research stations that were located in East Bengal and West Punjab. In addition, the remaining local scientists in most countries were cut off from scientists outside the country because their

links to the colonial research networks were severed. Personal contacts were reduced. Journals were less available and there were fewer opportunities to attend conferences. These factors appear to have reduced the productivity of research and general confidence in public research.

The supply of scientists did not start to expand rapidly until the 1960's when the development or expansion of agricultural universities in all of these countries and the training of large numbers of scientists in the West started to have some impact. The growth in number and quality of graduates was particularly impressive in India and the Philippines. Bangladesh and Pakistan lagged behind the other countries because their agricultural universities were not established until the mid-1960's.

The previous sections suggest three main reasons for underinvestment in agricultural research. First, private firms cannot capture a major share of the benefits from research and so although they may invest in research, it is less than the socially optimal amount. Second, many groups who would benefit from government research do not realize they can benefit and so they do not support government expenditure for research. Third, the people who expect to benefit from government research have no political power so they cannot provide sufficient support for research.

Research by private firms has been limited because the inherent difficulty of capturing returns to research, the small size of the market and government intervention limit the potential payoff from research. There are three categories of private firms that invest in research in Asia. The first type includes producers of agricultural products like large plantation owners or groups of farmers who jointly finance a research program. A second type which sometimes overlaps with the first is the processors of agricultural commodities like the cigarette companies, the sugar mills and the pineapple canners. The third type

is the input supplier. This includes seed companies, agricultural chemical companies, fertilizer producers, agricultural machinery firms, producers of cattle feed and others. In all of these countries, companies - especially the foreign companies - face government taxes, price controls and regulations which reduce their profits.

Government control varies greatly among our six countries. India has a maze of regulations. Thailand has the least regulations. In many of these countries, firms' profits are reduced further by government owned firms which compete directly with the private sector. Government competition is particularly strong in the input supply industry. If profits are reduced, firms have less ability and incentive to invest in general and less incentive to invest in research in particular.

The underinvestment in public research is due to insufficient actual demand for research either because people are unaware of potential benefits or do not have the power to turn latent demand into actual demand. A number of groups could gain from more public sector research. A major beneficiary of agricultural research in several of these countries has been the small farmer. In most Asian countries the majority of farmers have very little political influence. A second group which has benefitted from research are consumers who eat cheaper basic foods. Urban consumers are often politically important because they are well organized and closely connected to the governing elite. However, they are mainly interested in agriculture when there is a food crisis. The effects of new technology are frequently not apparent to them because they are filtered through a range of government programs like government grain procurement and imports, subsidized prices and ration shops. The third important group includes the well-organized cash crop and plantation sector. In some

countries this group's influence has suffered because of its colonial or multinational corporate connections. In addition it has supported private research instead of the government research program. The fourth group is processors. In several countries processors provide less support for research now because they have been nationalized or taxed into unprofitability. The fifth group is input supply companies which could benefit from new products and from cooperation with government research programs. Unfortunately, in many countries the relationship between the public and private sector scientists is one of antagonism rather than cooperation. Therefore, private sector scientists have not been vocal supporters of government research. Sixth, intellectuals in several countries have been disillusioned by the criticisms of the first round problems of the Green Revolution.

Since Independence, research--particularly on foodgrains--has had to depend on food crises for support. The more stable support of organized clients operates only for a few crops or regions and several of these client groups have become less active since Independence. Therefore, as the food crisis becomes less acute in Asia, there is a serious potential problem of continuing financial support even at today's relatively low levels.

Chapter 3

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Chapter 4 Development and Change in Asian Agricultural Research Institutions

Determinants of Institutional Change

In order to improve the allocation of research resources and increase the total amount of investment in research policy-makers and administrators must understand the determinants of institutional change. The case studies of export crops and foodgrain research in Chapter 3 have shown that institutional changes took place as a result of the demands for new technology. For example, commodity organizations established research programs when the need for sugarcane, jute and tea production technology arose. In addition inadequate institutions appear to be one cause of underinvestment in research. The institutional constraint is that farmers have little political power in several of these countries. An additional problem which concerns both the local government and donors is the efficiency of the Asian research systems. Efficiency questions ask whether the most appropriate technology is being produced per research input and whether this technology reaches farmers. The structure of the research institutions and their ability to plan, to motivate scientists, and to change when necessary will determine their efficiency. The linkages with extension and education and the size and quality of the extension and educational system will determine the efficiency with which the technology is transfered.

If Asian governments or donors want to increase investment, improve the allocation of research resources or improve efficiency they will have to change institutions. To do this effectively requires a basic model of how institutions change. This section first discusses a simple model of institutional change, then discusses some historical examples of change and their causes.

The Supply and Demand for Institutional Change

The demand and supply for new research and extension institutions or changes in the old institutions that supply new technology are closely related to the supply and demand of new agricultural technology. It is important to explicitly identify the factors that determine institutional change. There are several general factors that cause shifts in the demand for institutional change. First, there are new demands for technology that cannot be met by old institutions. For example, new pest problems may require new research programs to develop methods to develop the proper plant protection measures. Second, scientific breakthroughs may require new institutional arrangements to be efficiently exploited. Changes in research institutions in order to exploit the new biotechnology techniques is a good example of this. Countries and large corporations are setting up new research programs while universities are reorganizing theirs. Third, shifts in the demand for institutional change can be caused by changes in the ideology or values of society. Increased concern for animal rights, the problems of poor farmers or ecological problems may require new types of research institutions. Fourth, changes in the power of various political groups who are interested in research can also cause demand for institutional changes which they hope will cut costs or increase efficiency.

Government or corporate officials respond to these demands by "supplying" institutional changes. Government officials are motivated to make these changes because their power and jobs depend on having a productive research system which fulfills the needs of the politically powerful groups in society. Research administrators in the private sector want to increase the company's profits by

developing profitable new technology, which can be sold as a new product or used to reduce the cost of production, and thereby cut research costs.

There are three requirements for the supply institutional change. First, feasible plans and ideas for the structure of the new institution must exist. Many individuals and institutions contribute to the supply of plans or ideas. Communications between government officials or scientists from different countries allow research institutions to borrow institutional ideas. Social scientists, lawyers, journalists and politicians provide ideas. Public research institutions grow by trial and error. Foreign aid agencies, foundations and private consultants provide new ideas. Second, political power is needed to push an institutional change through the political or corporate bureaucracy. Supporters of an institutional innovation use their time and political capital to build support for innovation within the bureaucracy. This requires leadership or what might be termed institutional entrepreneurship. Third, once the change is approved, financial and human resources are required to implement the change. If these resources are missing, the institutional will exist on paper but will have no substance.

Shifts in the supply of institutional change can be caused by a number of factors. First, new institutional ideas can be caused by the growth of social science knowledge about institutional development and management, by reductions in the cost of consultants or social scientists due to foreign aid, by more open discussion of a system's faults, or by more communication about what has worked and what has not worked in other institutions and countries. The supply of institutional change in the private sector will be shifted by the same factors. Changes in government restrictions on joint ventures with foreign firms and more foreign investment and foreign trade will increase the supply of institutional

change to the private sector. Second, changes in political power within the government or corporation shift the supply of institutional innovation. The rise of new leaders will bring new ideas with them. Sudden changes of leadership due to elections, coups, etc. can realign power and cause institutional change. Third, changes in the financial and human resources for institutional change also influence the number and type of innovations. Companies that are making large profits can afford to invest in a new research division while companies that are losing money may have to cut such institutions. Governments with new sources of revenue such as taxes, profits from oil sales or foreign aid can build new institutions more easily than countries restricted to constant budgets. Countries with declining budgets will generally emphasize cost reducing institutional change.

Examples of Institutional Change

The colonial period foreshadows many of the major forces of institutional change that present day reformers face. For example, demand for new technology led to the development of new institutions to conduct and support research. Export demand for sugar, coffee, tea and jute combined with specific supply constraints such as disease, insect and quality problems led the producers or processors of these commodities to establish the first research institutions on these crops in Indonesia (then Netherlands East Indies), British Malaya, Ceylon and British India. It is important to note that the demand for research was also a demand for institutional change. In Indonesia, India, and Malaysia the expansion of export crops would not have occurred without scientific research. In the early 20th century there were virtually no research establishments in Asia capable of doing this research. The research institutions which had the

scientific capacity were in Europe, the U.S. or Japan. The only possible way to meet the need for new technology was to establish research institutions in Asia.

Major impetus for the establishment of new research institutions came from the Indian Famine Commissions, the Indian Cotton Committee, the Sugarcane Committee, and the Royal Commission on Agriculture in India. These commissions were created by Parliament in response to dissatisfaction with current institutions. The commissions included experienced administrators, academics and representatives of the Indian people. They frequently spent a year or more in India and England collecting testimony about the government's policies and institutions from business, government and academics. Regarding research the Royal Commission for Agriculture in India requested and received testimony on the Canadian, Australian and American systems. These commissions were responsible for the structures of the first Indian Agriculture Department, the Indian Central Cotton Committee (ICCC), the Indian Council of Agricultural Research, and later commodity research committees modelled after the ICCC. These commissions not only provided new ideas but played an important role in generating the political support required for approval of these changes.

Major political events also played an important role in inducing institutional change. In British India, the Independence movement and the desire to develop democratic institutions led to decentralization of government power. In 1919 a number of changes took place in the government. The Indian Department of Agriculture was split into provincial departments of agriculture. Only the scientists at the Pusa Institute and some administrators remained with the central government. There was no common program and very little communication between scientists of different provinces.

During the next few years there was a growing feeling that something had to be done because progress in solving agricultural problems was not moving fast

enough and because some problems were being completely neglected. The Royal Commission on Agriculture in 1926 provided a public forum in which these views could be expressed. It recommended the establishment of an Imperial Council of Agricultural Research to provide guidance and to stimulate provincial research through publications, conferences and grants. It was several years before this reform could be pushed through the bureaucracy and the Council was not established until 1929. The Depression and the financial problems of the Indian government prevented the Council from having an impact on research priorities until the mid-1930's.

Since World War II there is evidence of the same basic forces at work. All of the countries in the study except Thailand achieved independence after WWII. Independence led to changes in the demand for research because some groups closely associated with the colonial regime lost power. The amount and quality of research by private commodity groups declined in several countries. In others the relative size of the private sector declined because of increased expenditures on government research. In Indonesia the departure of Dutch estate owners and the decline of the plantation sector caused the demand for technology to decline. The absence of Dutch scientists during the 1940's and their final departure in the late 1950's reduced the productivity of and demand for the commodity institutes. In other countries new institutions were required to replace those that were lost because of boundary changes. The Pakistan government had to finance new sugarcane and tea research programs and private tobacco companies had to set up new applied research programs to meet the needs of Pakistan markets.

No major changes in most research institutions took place in the first decade after Independence. Most new governments retained the old structure.

The demand for research in most countries was not changed greatly because producers of export and cash crops remained the best organized lobbies for research. Exports continued to be very important to those in positions of economic and political power. Food was not a major problem immediately after Independence. Although the ruling elite was no longer colonial, the major government institutions and the politically influential groups who were interested in research were already in place before Independence. Therefore, not much changed.

Considerable fragmentation of the public research systems took place during the first decade of Independence. Demands by organized producer groups led India to continue the trend which started before Independence toward research organized around central commodity institutes financed by taxes on producers. The establishment of provincial agricultural universities also encouraged fragmentation in India and Pakistan. In the Philippines commodity based institutions proliferated. Government-assisted commodity organizations were a response to export demands and the governments' desire to finance more research without using general revenue or foreign aid. In Indonesia the deterioration of the internal political situation after 1960 led to the fragmentation of the research system (Mangundojo, 1971: 41). In Bangladesh the creation of new Ministries and autonomous institutes after Independence fragmented the research system. Demand for "atomic" agriculture led to the establishment institutions for nuclear agriculture in Pakistan, Bangladesh and Indonesia. In several countries these institutional changes were encouraged by the availability of foreign aid which financed the changes.

Fragmentation led to important inefficiencies in the research system. These inefficiencies led to pressure from some scientists and officials elsewhere in government to create a centralized coordinating council such as Agricultural Research Council. This institutional change did not occur until

political power in some of the larger countries was centralized. In four of our countries, greater centralization led to a more centralized research system. The strengthening of the Indian Council of Agricultural Research has been a gradual process as has been the centralization of political power in India. In the Philippines PCAARD was established soon after martial law. Martial law in Pakistan in the late 1950's was followed by the attempted integration of all provinces of West Pakistan into one province. Government research institutes along with the rest of the agricultural institutions were integrated. When the provinces separated in 1970 the research system was split. After martial law returned in 1977, the Pakistan Council of Agricultural Research was given actual power for the first time. In 1968 and 1969 soon after General Suharto established his power in Indonesia, the first steps were taken to establish AARD in 1974.

On the supply side AID and other donors played an important role in bringing together local and foreign experts to provide ideas for the new structure. AID also provided part of the money necessary to finance the new institutions. Once the research councils were established, AID channelled its assistance to research through these councils which enhanced their power.

The food crises of the 1960's and 1970's and the early successes of the Green Revolution created considerable pressure for institutional change in the research systems. The public sector was pressured by rapidly rising food prices and expenditures for food imports. The governments responded by increasing the size of the foodgrain research program and by making institutional changes that were supposed to increase the efficiency of the research system. New research institutions were established to focus specifically on the major grain crops. In Bangladesh new autonomous research institutions were established. In most of the other countries national crop improvement research

programs were established which jointly planned and coordinated research in many different institutions. The All-India Coordinated Rice Improvement Project is an example of this type of organization.

During the 1960's and the 1970's there was an increase in the supply of ideas for institutional change. The Ford and Rockefeller Foundations were a source of ideas and money for institutional change. The International Centers like IRRI and CIMMYT developed new methods of doing foodgrain research. These included new methods for breeding and screening new varieties which required institutional change to do the research and multisite testing of varieties. They encouraged national systems to organize multidisciplinary research teams around a commodity or problem. The success of the green revolution attracted the attention of intellectuals to the role of agricultural research in producing important new technology. There was considerable criticism of research systems that did not meet the needs of the poor or of certain regions of the countries. This led to institutional innovations such as geographic decentralization and farming systems research in which research systems tried to develop programs that would help the small farmer and the rainfed regions that had not benefitted from the Green Revolution. The success of the International Centers emphasized the possibilities of increasing agricultural production through research to the donors. These donors started investing heavily in research at this time. The donors financed research on research institutions and provided consultants and resident scientists from the West who had many ideas about how a research system should be structured.

It is important to note that institutional changes do not last unless a strong demand for them exists, they are able to build up a political constituency (if it is a public institution) or they can show that they are increasing

the profitability of the firm. The decline in some export crop research organizations has been due to declining demand for their services by the private sector. One institutional change which did not last was the unification of the palm oil research institute with the Malaysian Agricultural Research Development Institute. The reason for the split was that palm oil growers felt that oil palms were not receiving sufficient resources. The slow development of the Pakistan Agricultural Research Council was due to strong regional powers which fought centralization. The entrenched forces behind the traditional separation of research, extension and education in many states in India prevented the unification of these services in many states in India (Randhawa, 1979).

There is evidence that a research system can turn latent demand into actual demand. Early British scientists in India chose their research priorities to get the "big bang"--highly visible results--which would generate demand for the new research institutions. Several Asian systems have been able to use the favorable publicity generated by the Green Revolution to turn latent demand into actual demand for foodgrain research institutes.

There are some recent examples where government research institutions have organized new institutions to support research. This is part of the process by which latent demand for research is transformed into actual demand for research. The Philippines Tobacco Research and Training Center (PTRTC) was established in 1977 in response to a recognized need by processors and some people in the national research system (Pray, 1984). They have been able to establish an organization of farmers which has increased the efficiency of PTRTCs research and technology transfer and has provided them with a political support base among their clientele. Their first step in developing support was to develop some improved technology which would improve farmers' incomes. The second step was to involve the farmers in their research and extension efforts. The final

step was to organize farmers into an organization called the Federation of Outstanding Tobacco Farmers of the Philippines (FOTFP) which brings prestige and financial benefits to farmers. At the same time it gives farmers the power to lobby for more government support for the PTRTC.

There are also examples of institutions that stand in the way of developing political support. It would appear that farmers, the government extension system, public and private suppliers of new inputs, and the research system all have much to gain by supporting each other to help information move efficiently between research institutes and farmers. In many countries these institutions act like competitors rather than mutually dependent institutions.

The benefits from working together have been disguised by two factors. First, many Asian governments are very centralized and farmers have little political power. Scientists have little to gain in the short run from improving their linkages to farmers. As a result, researchers follow their own intellectual interests which may or may not be influenced by farmers' real problems. Not surprisingly when farmers see what researchers are doing, they say their work has no relevance and they have no need for the scientists.

Second, the government research, extension and input supply institutions may be organized as rivals for funds from both the government and foreign donors. This problem is exemplified by the Bangladesh system. In Bangladesh neither the seed industry nor the extension service are under the control of the research system. As a result it is much more difficult for the research service to develop its support. The most immediate beneficiaries of the research system--the growers of improved seed--have no incentive to support the research system. The government through the Bangladesh Agricultural Development Corporation (BADC) has monopoly control over the first few rounds of seed

multiplication. The contract growers in the later rounds have no direct connection to the research system. Instead their contract is with BADC. BADC is not likely to give much credit to the research system because they see themselves as a rival to the research system for funds (which they are since they both get funds from the Ministry of Agriculture and from the same foreign aid donors). BADC would like to do more of the applied research such as variety introduction and variety testing. It claims that it needs to do this because the research system is weak, slow and inefficient. At present BADC is under attack from the donors and the free enterprise people in the government. Pesticide distribution has been turned over to the private sector, tube-well and fertilizer distribution is in the process of being privatized and some people would like the private sector to be more involved in seed multiplication and distribution. Thus, BADC is under attack and is not likely to provide much support for research which is growing rapidly.

Extension is also a separate service from research and like BADC has little incentive to give research any credit for successful research. The extension service has to compete with BADC and research organizations for funds from the Ministry of Agriculture and foreign donors. Thus, a budget maximizing bureaucrat in the extension service might well decide to give research as little credit as possible particularly if there are personal rivalries between the heads of the research and extension system.

Organizing the Demand for Research

Research systems must allocate research resources in such a way that they will get political support for their budget. To do this they must determine where the major economic payoffs to society will be and also what politically powerful groups in society want from research. If these criteria lead to the

same set of research priorities there is no problem. However, frequently the research system will have to trade some of the research priorities which would maximize the benefits to society in order to get political support which will enable the system to increase the size of the entire budget.

Governments cannot encourage the private sector to import technology, to do research or to transfer technology to farmers unless private firms are allowed to make a profit. The demand for private sector research depends on potential profits. Tax exemptions for research expenditures are a small incentive for research when a government keeps a major share of markets for itself.

The economic demand for government research is not effectively articulated because potential beneficiaries are unaware and/or do not have political power to demand research. Research leaders must do what they can to build the institutions which can articulate these forces. This implies that research systems should invest in:

1. identifying the underlying economic trends or problems of society,
2. educating society that research can do something about them, and
3. organizing groups which will speed flow of technology to clients and also give clients the power to support research.

There are several trends which countries should keep in mind when planning for the future. First, the current support for government research funding is threatened by the achievement of self-sufficiency in foodgrains in several countries, by pressures to cut government budgets caused by debt problems, and by declining foreign aid. Second, the demand for technology is likely to change in Asia as population growth starts to slow down and urbanization increases. Third, the new biotechnology will create demand for biotechnology institutes but will be producing few tangible results in the next decade. The potential of biotechnology has led many private companies to increase their investment in

agricultural research. In the future more technology will be made available by private companies rather than public institutions. Fourth, the demand for private sector research will grow but government policies will determine how fast and in which countries. Fifth, foodgrain research lobbies are emerging in some places and there is the potential for more to develop in the future. In the Punjab and in Tamil Nadu in India progressive farmers are starting to organize themselves to pressure the government for price controls on inputs and price supports for their output. In the Punjab they already constitute a major lobby for research at the agricultural university. In Tamil Nadu this support remains only latent demand at the moment. The input supply companies in several countries are starting to organize and build their political power. They have an interest in a strong agricultural research, extension and education program.

Lessons

Potential reformers of the research systems have to do at least four things: (1) identify demand for institutional change; (2) produce a feasible innovation that will meet this demand; (3) develop the power within the organization to get internal approval, (4) arrange the human, physical and financial resources to implement the change. Reformers must make sure they have considered all of these factors before launching a reform program.

Second, major changes in institutions must be consistent with the major economic forces and political structures of the country. The Philippine tobacco growers were organized around the need for new technology and better prices. Centralization of several research systems took place when the government as a whole became more centralized. When centralization in the form of an agricultural research council was attempted in Pakistan in the late 1960s it was not

successful because the provinces were still very strong. When the center took more power the council became more powerful.

Third, when exogenous forces create the demand for new technology, scientists and research administrators should be ready to take advantage of the opportunity not only to expand research budgets but also to create research institutions that will be more efficient. One Asian research director told of attempting to use the enthusiasm for nuclear agriculture as a way of introducing the importance of basic research institutions in an LDC. Many Asian research institutions have used the enthusiasm for the Green Revolution to reform their research systems into multidisciplinary teams working on the problems of specific commodities.

Fourth, research systems can build a support organization for research as the Philippine tobacco example shows. This requires that a research system invest substantial resources in communication and organization or that the extension and education system build support for research. However, as the Bangladesh example shows the extension and education systems will not help build support if they are competing with research for funds.

Fifth, foreign aid agencies can be a useful ally in supplying institutional change. This is discussed in more detail in the next chapter, but it is useful to mention several points in the context of this chapter. Donors can be a useful source of new ideas. They can provide the resources needed to carry out the initial phases of the change. They cannot create demand for institutional change. In some cases foreign support could be a liability when trying to develop internal support, but frequently the promise of money will help build internal support.

Chapter 4

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Pray, Carl E. (1984), "Mobilizing Support for Agricultural Research," in Agricultural Research Policy, Vernon W. Ruttan, University of Minnesota, Economic Development Center.

Randhawa, M.S. (1979), A History of the Indian Council of Agricultural Research (New Delhi: ICAR).

Chapter 5 Impact of AID

This chapter uses the framework of induced technical change and induced institutional change to examine the impact of USAID on Asian research institutions. The first part is a descriptive history of AID's assistance to agricultural research, extension and higher education in Asia. The second part discusses the impact of AID on the size and allocation of research resources by commodities and countries. The third part examines the effect of AID activities on the organization and structure of research. The final section discusses first alternative means of providing assistance and their priorities within the project framework.

Allocation of AID Resources Between Education, Research and Extension

After World War II there was concensus in the U.S. that we had a responsibility to help overcome world hunger. The motivation behind this concensus was largely humanitarian but also involved self-interest. The Communist threat in Europe motivated the Marshall Plan which provided both foodaid and a limited amount of aid for technical assistance to agriculture. In Asia, the Communist takeover in China, then the war in Korea led many groups in the U.S. to believe that political stability in South and Southeast Asia was essential to U.S. interests. These groups felt that one essential part of political stability was sufficient food (Rosen, 1982).

U.S. officials then had to decide how to best use government resources in order to help overcome hunger. It was agreed that new technology was essential to increase the productivity of Asian agriculture. It was decided that sufficient technology was available either from research institutions in the West or in Asia, but that the transfer of technology first from the West to Asia

and then to the farmers through extension was needed. In the 1950's AID's primary emphasis in agriculture was on extension and rural development. There was scattered support for research in the form of scientists who assisted in rice and maize breeding programs in the Philippines, rice breeding and soil research in Thailand and soil research in India (Moseman, 1970: 70, 73). Extension, however, dominated AID's program.

The reason that technology transfers through extension was emphasized instead of research are not clear. Moseman (1970: 69) has suggested that because the Marshall Plan corn program was successful in Europe people concluded that similar programs in Asia would be equally successful. The corn program had provided hybrids, inbred lines and a minimal amount of technical assistance to help set up regional testing programs. Leaders of the early U.S. programs missed the point that parts of Europe, such as the PoValley, had climates similar to ones in the U.S. while Asia was quite different. Moseman suggests that the short-term outlook of the Agency which made long term research less attractive than extension also contributed to this decision. Krueger and Ruttan (1983: 9-23) offer an additional explanation for the extension bias. They say, "There was a firm conviction among U.S. development assistance personnel and on the part of many U.S. scholars that inefficient resource allocation among 'irrational tradition bound' peasants was a major constraint on agricultural development."

Once the extension bias was established it was able to perpetuate itself. The first people hired in agriculture were trained and had worked in extension rather than research. They maintained a bias toward extension as they rose through the ranks.

In the late-1950's, projects to assist agricultural universities were initiated in a number of Asian countries. The first program was Cornell University's

in the Philippines in 1952. It's mandate was to rehabilitate the agricultural college at Los Banos that had been destroyed during World War II. In 1959 the era of university building began in South Asia with the establishment of the Uttar Pradesh Agricultural University in Pantnagar, India. By the mid-1960's AID was supporting university building programs in six Indian provinces and in each of the countries of this study.

These universities were an attempt to transfer to Asia an institution that had been very successful in developing and transferring technology in the U.S. The creation of the university systems in the 1960's was in part a response to the failures of extension programs in the 1950's. They were set up to provide better training to extension workers and farmers and also to do research which would provide new technology to farmers. It was also hoped that they would generate new technology. This was generally not the case. "Although there is a general impression that the land grant universities are assisting in establishing institutions in the developing nations with combined attention to education, research and extension, the major emphasis in most of these countries has been on teaching programs. The research input has been modest or entirely lacking--present to the degree that individual U.S. specialists had an interest and opportunity to carry out selected projects." (Moseman, 1970: 73).

The World Food and Nutrition Study quotes Moseman who worked for AID in 1966 as saying, "We have not focused research attention on the increase of production of crops such as rice and wheat, which have been in surplus in the United States. This reflected the attitude of the Congress, of the American public, and of the American farm organizations--a handicap still to be overcome." (World, 1978: 95). AID was not allowed to support research on certain crops. In some cases AID personnel may have seen the agricultural universities as a way to assist research on some of these crops.

AID had three types of projects which funded research programs in the late 1960's. The first project was the Northeastern Thailand Research Project in 1966. This was followed by projects in India in 1967, in Pakistan 1969, and in East Pakistan in 1970. The primary goal of these projects was to increase foodgrain production. Most project funds went to government research institutions in Asia. Funds were used to provide capital for buildings and equipment, money for training scientists and technicians, technical assistance for long and short-term consultants or members of USAID staff to work with the institutions, and sometimes funds were used to carry out research. The second type of AID project support for research did not focus directly on strengthening research institutions. These projects developed small scale irrigation, strengthened agricultural universities and supported reforestation. A portion of the funds, however, was set aside to do research or strengthen the research capacity of institutions related to the project. A third type of support for agricultural research has been financing the core budget of the IARC's. AID first provided assistance to CIMMYT in 1969 and then to IRRI in 1970.

Food shortages in Asia particularly India in 1964 and 1965 and the early success of IRRI rice and CIMMYT wheat varieties spurred AID's interest in assisting research. The food shortages dramatized the need for more action to overcome hunger. The success of the new varieties convinced many USAID missions that large benefits were possible from foodgrain research in Asia. The publicity that accompanied the Green Revolution showed governments in developing countries and the U.S. public and Congress that foodaid was not the long term solution to world hunger.

By this time people were disillusioned with the emphasis on extension. According to Krueger and Ruttan (1983: 9-24), "By the mid-1960's there was considerable disillusionment among the administrators of development assistance

programs and by development scholars with the impact of assistance for the development of agricultural extension programs. It became apparent that agricultural technology was much more location-specific than had been anticipated. A new generation of scholars began to look upon peasants in developing countries as 'poor but efficient'!

In 1966 President Johnson suggested that the restriction against supporting foodgrain production be eliminated. By 1968 the policy was officially changed (World, 1977: 96). Other constraints existed at that time however. In 1967 AID lost the few people who had any experience with research (Moseman, 1970: 75) and Congress placed a limit on how much research AID/Washington could finance (World, 1977: 96). These constraints do not seem to have inhibited mission funding of research projects.

In the 1970's major new research institution building projects were financed in Indonesia, Bangladesh, and the Philippines. AID expenditures on research in Thailand gradually tapered off while spending in Pakistan grew slowly until the end of the decade when it increased rapidly. In India all aid was cut off for political reasons and in 1973 most support for research projects and the Universities was terminated. Within AID the recognition that national research systems had to be strengthened in order to continue the spread of technology from the IARC's led to an overall increase in support for research. Food shortages and high international food prices in the early 1970's strengthened the belief that more work on agriculture was essential. The forecasts of foodgrain shortages in LDC's (Fox and Ruttan, 1983) kept this problem before the American public. There was growing criticism of research because of the criticism of the green revolution which indicated that some regions and social groups had not received any benefits from the new technology. At the same time donors' assistance strategy was shifting from general development to basic needs.

Allocation of Assistance Between Countries, Commodities and Projects

Available information on the size of AID's assistance to research and education in 1970 is shown in Table 5.1. It includes only major institution building projects and misses the research projects which are components of other projects.

Table 5.1. AID Assistance to Agricultural Research and Education, 1970 (Annual)

	Research		Ag. Universities
	Expenditure	Commodity	
India	100,000	Rice	1,862,000
Pakistan	100,000	All	a.
Bangladesh	165,000	Rice	a.
Thailand	815,000	All	0
Philippines	0	None	0
Indonesia	0	None	1,232,000
CIMMYT and IRRI	1,192,000	Rice, Wheat, Barley, Corn	

a. There were programs to build universities but we do not have annual data on AID expenditure.

The research projects in India, Bangladesh, CIMMYT and IRRI concentrated on major foodgrains. The goal of the Pakistan project was to build up PARC which primarily funds research on foodgrains. The Thai project was the most diversified - dealing with all types of crops in the Northeast.

Financial support from AID for building agricultural research institutions and financing agricultural universities has continued in the 1980's. AID agricultural research projects exist in all six countries of this study and agricultural universities in Thailand, Philippines, Indonesia and Pakistan continue to receive support.

The Asia Bureau with a few exceptions funds only research which is part of an institution building program.[1/] It funds the development of agricultural universities, scholarships to study science overseas, the physical plant of experiment stations and the technical assistance needed to get these stations started. At the same time it has financed research projects to build institutional capacity.

Research has been a component of other types of projects. A number of irrigation and drainage projects have research subprojects which deal with socio-economic, management, agronomic and engineering problems. Several projects on natural resource management and forestry include funds for research, technical assistance and commodities. Of the 40 Asia Bureau projects which contained research in 1982 not more than five were only financing research. Two of these were in India and the money went to well-developed research institutions. The other three went to carry out policy research in Bangladesh, Indonesia and Thailand. In total, roughly 30 percent of the expenditure went to finance actual research while 70 percent was used for building research institutions.

The pattern of expenditure on agricultural research projects is shown in Tables 5.2, 5.3, and 5.4. Table 5.2 separates expenditure by country. The major recipients of total funding for research are Indonesia and Bangladesh which account for over half of the total. They are followed by the Philippines, India, and Sri Lanka which receive about 30 percent of the expenditure. Research expenditure in Pakistan is expected to grow most rapidly, but it will continue to grow in India and Sri Lanka.

1/ The analysis in this section is based on a review of all Asia Bureau agricultural and rural development projects which were being executed or in the pipeline in the Fall of 1982.

Table 5.2 AID/Asia Bureau Research Projects: Annual Expenditure by Country (1982).

Country	Allocation ($1000)	Allocation %
Nepal	2535	6
Sri Lanka	3365	8
India	4212	10
Bangladesh	9021	21
Pakistan	1200	3
Burma	800	2
Philippines	4565	11
Thailand	2260	5
Indonesia	13027	31
South Pacific	200	-
Asian Regional	1198	3
Total	42383	100

Source: Unpublished USAID Documents.

Table 5.3 Asian Bureau Expenditures on Research and Research Institution Building by Commodity Groups (1982)

	Allocation	
	Exp. ($1000)	%
Major foodgrains[1] (rice, wheat, corn)	11848	50
Minor foodgrains[2] pulses, oil-seeds, root crops	9121	39
Nonfood crops[3]	0	0
Animals	0	0
Fish	695	3
Forest products	1980	8
Total	23644	100

[1] Plant production identified with these crops + irrigation and drainage + 1/2 farming systems.

[2] Plant production identified with these crops + 1/2 farming systems.

[3] Actually some research under Indonesia projects and some under irrigation + farming systems.

Source: Unpublished USAID documents.

Table 5.4 Research and Institution Building by USAID Research Categories (1982).

	Allocation ($1000)
I. Natural resources	10408
1.1 Land, water and air	8428
1.1.1 Soil and water	1873
1.1.3 Irrigation and drainage	5185
1.1.4 Aquaculture and fisheries	695
1.2 Forest, range, wildlife	1980
II. Production and protection	17298
2.1 Plant production	9580
2.2 Plant protection	1002
2.3 Animal production	
2.4 Animal protection	
2.5 Production systems	6716
2.5.1 Intensification	5418
2.5.2 Mechanization	1298
III. Processing and distribution	309
3.1 Food systems	167
3.2 Other crop systems	142
IV. Applied social science research	3500
4.5 Agriculture and food policy	3122
V. Research facilities	11241

Source: Unpublished USAID documents.

Table 5.3 shows research expenditure by commodity group. At present major foodgrains account for half of the expenditure, other foodcrops 39 percent, and forest and fish split the remaining 11 percent. Nonfood crops and animal agriculture appear to receive nothing. This is an exaggeration. Some nonfood crops such as cotton are undoubtedly affected by the irrigation research and farming systems research projects in some countries. Some of the work on forest products includes research on forages and range management and some farming systems and irrigation management projects examine fodder production. It is clear from an examination of these projects, however, that nonfood crops and animal production do receive the least research resources.

The trend in commodity priorities is to gradually deemphasize the major foodgrains. More emphasis is being placed on pulses, oilseeds and rootcrops. Forest management and agroforestry in South Asia and in fisheries in Southeast Asia are of increasing interest.

Another way to disaggregate research is by USDA categories (Table 5.4). Plant production research (2 1) which accounts for 9.5 million dollars is a major category of expenditure. This is followed by production systems research (2.5) at 6.7 million dollars then irrigation and drainage research (1.1.3) at 5.1 million dollars.[1/] The fourth major category is agriculture and food policy research (4.5) which is 3.1 million dollars. Forest, range, wildlife management (1.2) together with the watershed management part of soil and water research (1.1.1) receive about 3 million dollars. Several important areas receive little funding in Asia. These include soil management, animal production and

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1/ Production systems research includes AID's farming systems reseearch projects. Irrigation and drainage research includes AID's water management research projects.

protection, processing and distribution, fisheries, and plant protection. The areas of growth in the near future on the basis of proposed projects seem to be water management, farming systems, aqua-culture and food policy and as noted above, forestry research in South Asia and fisheries in Southeast Asia.

It was not possible to quantify the funds to different disciplines. There are several observations that do seem justified, however. First, a surprisingly large amount of money goes to social science research. In addition to the $3.6 million in category IV in Table 5.4, social science research receives a substantial part of the resources that are allocated to natural resource and production systems research. Social science research is one of the fastest growing areas of expenditure because natural resource, production systems and food policy research were all targeted as rapid growth areas. Plant breeding may still be the single most important discipline but as farming systems grows, the general agronomist may play a more important role. We have already noted that some areas such as the animal sciences are neglected.

It appears that AID and the other donors have introduced another less positive bias into the allocation of research resources. AID's provision of cheap capital seems to have skewed research in a capital intensive direction. Most countries received USAID assistance in the form of grants or low interest loans, which could only be spent on training, technical assistance or capital goods including buildings, equipment, and transportation. Thus, these goods were available to the government at interest rates far below the market rate. The result was that governments substituted capital for labor.

The evidence of this is scattered. The Minnesota teams' visits to both Indonesia (Cardwell et. al., 1981) and the Philippines (Evenson et. al., 1981) commented on the unused or underutilized equipment and buildings. Local research systems in the private sector or ones based only on local resources

frequently spend far less on permanent research stations and do more research in farmers' fields. For example, Bangladeah Tobacco Company (BTC) does all of its research on farmers' fields. It leases some plots but does not own any experiment stations in Bangladesh. Comilla academy in Bangladesh did considerable applied research in farmers' fields or fields of the cooperative societies instead of constructing a large research facility.

In recent years AID appears to be cutting back on its funding for buildings. It has also taken steps in some countries to increase the supply of human capital by assisting in university building programs. These seem to be steps in the right direction.

Impact of AID on Institutional Structures

Foreign aid donors have played an important role in institutional change in Asian research systems since about 1960. They have tried to respond to local demands for institutional change. Their direct influence has been on the supply side although indirectly they may have influenced the demand for change by shifting the power of certain groups within a bureaucracy. AID has provided ideas for new institutional structures and the money to finance change. Donors cannot provide the political power needed to get approval for the change but the availability of funds to implement a change frequently provides an incentive for governments and individuals within the government to incur the cost of building the necessary political coalition. In addition, donor support for a change - particularly if backed up by research - may help convince those in authority to approve the proposed change.

Who Does the Research?

There is little evidence that the growth of AID financed government programs crowded out private research. Private and semi-government commodity

organizations which financed research on cash and export crops declined in importance in the 1950's and 1960's in Indonesia, India, East Pakistan and probably the Philippines (Pray, 1983). In Indonesia the declines were associated with anticolonial sentiment, especially in the sugar industry. The nationalization of certain industries and the growth of government research led to the decline of private research in South Asia. This decline took place before AID started to finance research projects. Government research programs funded by AID since the late 1960's were primarily foodgrain programs. The social returns from such projects were far higher than the gains any one company could collect with the possible exception of hybrid corn and millet research. In the absence of government programs there would have been little or no private biological research on foodgrains. In 1970 private companies started to do research on maize, sorghum, and millets in 1970, in spite of the fact that AID was assisting government research.

Some of AID's activities indirectly either increased the demand for private research or reduced the cost of supplying new technology through research. AID's university building projects and training of scientists in U.S. and elsewhere has reduced the cost of scientists and technicians to the private sector. Interviews with private companies in Pakistan, the Philippines and Thailand indicate that most of the scientists who work in the private sector were trained in the U.S. with USAID money or at agricultural universities which were partially funded by AID. Typically, they worked a number of years in the public sector then shifted to the private sector. The salesmen, technicians and some of the management of these companies also were trained at these agricultural universities.

In some countries, agricultural universities and government research programs have been a source of ideas or inputs for private research programs or

have provided prototypes which the private sector has improved. Thailand and the India agricultural universities have released inbred lines of maize to the private sector which seed companies can then use to breed their own varieties. The Punjab Agricultural University developed a thresher which the private sector built. The thresher has achieved considerable popularity and has been improved by its manufacturers.

AID has also strengthened the private sector in other ways. In India AID personnel helped organize the pesticide and fertilizer industry associations which include both private and government corporations and sponsor applied research. AID's programs have helped change policies in Bangladesh and Pakistan from government distribution of pesticides and fertilizers to private distribution. This has spurred applied research by companies in both countries.

Changes in Government Research Institutions

AID projects have assisted four types of changes in the internal organization of research institutions in Asia. First, the major AID agricultural research projects of the 1970's in all six countries except Thailand financed increased institutional and in some cases geographic centralization of the research system. These projects supported the establishment or strengthening of agricultural research councils in all countries except Thailand. Second, in the 1980's research projects have focused on geographic decentralization of research by supporting regional research stations or universities in all countries except India and farming systems research programs in all countries except India and Thailand. Third, AID pushed for greater autonomy for the research system from the regular government institutions. Fourth, AID promoted multidisciplinary research programs organized around commodities or problems instead of programs organized around disciplines. AID's explicit reason for

all four of these changes was to improve the efficiency of the research systems.

Centralization of these government research institutions was preceded by a period of institutional fragmentation in the 1950's and 1960's. The research system was often fragmented into many institutions in many different ministries. Geographic decentralization of the research system was a problem in some countries. India was the extreme example but it was also a problem in Pakistan, the Philippines and Indonesia. In response to this problem the agricultural research council model became very popular with the host countries and AID.

These councils loosely followed the Indian model and all of them had the same objectives--more coordination, communication and control. The structures and actual powers of these councils are now different in each country. The Pakistan Agricultural Research Council has its own research facilities while the Philippine Council is strictly a planning and advisory council. Some councils such as PCARRD in the Philippines actually have the power to set priorities for the entire country while others like the BARC in Bangladesh until recently had to rely on persuasion. The councils also vary in the amount farmers, agribusiness, ministries, and scientists from other institutions participate in the decision-making process.

AID played a fairly important role in this institutional change. It financed missions to study research systems and recommend institutional changes like the adoption of a council of some type. Second, it financed technical assistance, the cost of buildings and training staff for the councils. Third, it channelled money for agricultural research through these councils which gave the councils considerable power to allocate resources. Fourth, it financed national commodity research programs which were some of the more effective means

to coordinate research and show cooperating research institutions that the councils could indeed play a useful role.

Pakistan shows, however, that good local leadership and political and economic pressure for centralization are essential (Pray, et al 1982). Pakistani and outside experts recommended a stronger council in 1968 and USAID contributed millions of dollars to strengthen the Council. The provincial governments feared the loss of power and resources to the council and were able to prevent it from achieving any real power. In 1977 General Zia became president of Pakistan. A new leader of the Council was selected. In 1978 a wheat rust epidemic occurred. The council leadership was able to use the epidemic as proof that provincial research institutions were not doing an adequate job. This helped convince the President and other officials in Islamabad that a stronger Council was needed. In 1978 and 1979, the Central government gave PARC more functional autonomy and real power over research. In total it took almost 10 years from the time AID started to assist the Council for it to develop any real power.

Geographic decentralization has recently become an important theme of AID assistance to research systems. The slow diffusion of new rice varieties in some countries emphasized the importance of developing varieties for different agroclimatic regions. Critics of the green revolution pointed out that many areas received no benefits from the first round of improved varieties. Emphasis on basic needs has focused AID's attention to regions with poor soil and water resources. Many countries have decentralized by building up scientific capacity at substations in different ecological regions and by setting up farming systems research programs around the country.

India has had a decentralized system since the 1920's. AID helped strengthen the components of that system in the 1960's with its agricultural

university projects. In Thailand, AID's major involvement in research, which started in 1967, was the development of the research station in Northeast Thailand. Since the mid-1970's AID has strengthened the agricultural university of Khon Kaen which is also in the Northeast Thailand. In the Philippines AID has financed PCAARD which has played an important role in building up regional research strength (Evenson et al, 1981). In Bangladesh AID financed the development of the BARI substation in the Northwestern section of the country in the late 1970's and now is financing the development of the regional stations of the Bangladesh Rice Research Institute. In Indonesia the major AID research projects have been building research institutions in Sumatra and the outer islands. Finally, in Pakistan AID recently started an agricultural university project in the Northwest Frontier Province which it hopes will strengthen the entire research, extension and education system there.

Decentralization has allowed scientists at headquarters an opportunity to try new varieties in a number of different locations. In Bangladesh and Indonesia decision making about the goals and priorities of the stations is still centralized. This means that research programs frequently do not respond to specific regional problems. In Bangladesh, recent evaluation teams (Anderson et al, 1983 and IRRI, 1983) found that the stations in Ishurdi and Barisal developed their own programs but the vast majority are primarily testing sites for experiments designed and managed from Dhaka.

An important reason that decision making in Bangladesh has not been decentralized is that the political structure is extremely centralized. Decentralized decision making may make the research system more efficient in the long run but payoffs are not likely to be visible. In Bangladesh there is no parliament. The pressure for local level research therefore must go through informal channels to the military or the civilian bureaucracy both of which are

highly centralized. The research budget is determined in Dhaka based on the bureaucracy's view of research achievements.

AID has assisted several research systems to achieve autonomy from regular civil service rules for scientists and to allow scientists rather than civil servants to lead research institutes. It has been concerned with manpower training, motivation, and retention for a long time. Scientific manpower is the key element in any research development project. As Moseman wrote in 1970 (p. 59), "The lack of scientific manpower is the major limiting factor in the upgrading of agriculture in most developing nations today." This situation would have been far worse if AID had not helped to train scientists. The AID research projects of the 1970's and 1980's usually had a training program as a major component. Research institutions and AID recognized that scientific facilities, working conditions, salaries and non-monetary incentives would have to be improved to retain and motivate highly trained scientists. Regular government civil service did not provide enough incentives so institutional changes were supported by AID in several countries. Autonomous research institutions were set up in Bangladesh, Indonesia and Pakistan. These institutions were financed by the government but had a board of directors to which they were ultimately responsible. These institutes raised salaries and were headed by scientists.

Other changes were introduced in the Philippines and India to improve the effectiveness and remuneration of scientists. In the Philippines PCAARD introduced a system in which researchers receive extra payments for participating in PCARRD sponsored research (Evenson, et al, 1981). In India a new government service just for agricultural scientists was established in the late 1970's (Randhawa, 1979).

Autonomy from the regular bureaucracy has improved the position of scientists in South Asia. Motivation and retention of scientists remains a problem. Even in autonomous institutions the governments limit salaries and benefits far below the level offered on the world market. In addition, few research institutions in Asia are able to match the facilities available in the West. Thus, some top scientists still leave the country or go to the private sector where salaries are higher. Indonesia seems to be the only country that does not have retention problems. Few scientists work in the West apparently for cultural reasons and as yet there is has little demand for scientists in the private sector in Indonesia. In Thailand leakage to the West is not a problem but some scientists have left jobs in the private sector as it has grown. Leakage means government research institutions must continually train new scientists and/or raise salaries. There is no cheap solution. In the long run the least expensive solution is undoubtedly to develop local agricultural universities which can supply inexpensive scientists. India and the Philippines have been able to develop such systems and AID is helping Indonesia and Pakistan to develop effective agricultural universities.

Multidisciplinary research on specific problems or commodities was the fourth type of institutional change which AID projects have encouraged. Most research systems inherited from colonial powers were organized on disciplinary lines. Early AID projects to build agricultural universities based on the American model encouraged this type of organization. The Rockefeller Foundation's work in Mexico and India and the success of IRRI's interdisciplinary program suggested that a new model for research programs might be more effective.

IRRI projects funded by AID or the combination of Ford Foundation and AID transferred the commodity based research structure to India, Indonesia and

Bangladesh. The Indonesian rice research program and Bangladesh Rice Research Institute are both close copies of IRRIs organization. IRRI attempted to transfer this structure but with somewhat less success to Pakistan and Thailand.

Multidisciplinary research is a basic principle of farming systems research. AID has been very involved in farming systems research in recent years and thus has been pushing this multidisciplinary approach there also.

These changes have improved the efficiency of the research system in most of these countries. It is clear that they are far from perfect. The current enthusiasm of local governments and donors for better research management reflects their dissatisfaction with the present situation. Long lasting changes in the centralization or decentralization of decision making will depend far more on the location of political power in the country than anything AID can do. AID can finance more educational institutions and training programs than it is doing at present. Ensuring that research systems continually invest sufficient resources in human capital is more difficult.

The Relationship Between Universities and Research Institutions

Important advantages for both education and research appear to exist if graduate training and research are conducted in the same institution. The research scientist keeps up with his field so that he can keep ahead of his students. He also benefits from the fresh ideas brought by the students. In addition, he gets inexpensive and talented research assistants. The education of the student is improved because he gets experience conducting research.

The demand for agricultural education may be working against a strong research program at universities. The demand for the services of agricultural universities in India comes mainly from students from elite families who want jobs in the government. If they want graduate education to become scientists,

they prefer to go to the West. In the past there was little demand for research from the agricultural universities either because there was little demand for any research or because there were other government institutions which were supposed to produce new technology.

During the 1960's AID tried to reproduce the American land grant universities in which research, extension and education were integrated into one institution. It was expected that these institutions would train research scientists and produce valuable research at the same time as they provided training to students who would become progressive farmers, extension agents and government bureaucrats. These institutions had been effective in the U.S. Both Indian officials and AID assumed that by financing similar institutional structures and hiring U.S. universities to provide leadership and advice these institutions could be successfully transferred to Asia. It is now clear that this transfer was only partially successful. These universities greatly increased the number of graduates available for government service and provided bachelor level training to future scientists. Many of these universities did not become major research universities and most do not produce Ph.D. level scientists.

There are some important exceptions. These include the Indian agricultural universities in Punjab, Karnatika and Tamil Nadu and the University of the Philippines in Los Banos. These universities have been important sources of new technology and scientists although the number of Ph.D.s produced is still quite limited. The thing that sets the successful Indian universities apart from the rest is that they were able to unify research, education and extension in one institution. In the Philippines the close tie between PCARRD and UPLB ensures funding for a strong research program. IRRI's presence at Los Banos acts as a stimulant to further research. Another less tangible factor which contributes to the success of the Indian universities is the pressure by farmers for

practical results. The Universities have proved themselves useful by producing improved technology. The farmers in these regions especially the Punjab have sufficient political power to put pressure on the Universities for continued results. The demand for higher degrees from India and Philippines has been important for a longer period of time than in the other countries. People from outside the Philippines come not only for UPLB's reputation but also because of its affiliation with IRRI.

Some of these universities have successfully copied the model of the land grant system -- teaching, research and extension is under one roof and they are producing new technology and scientists. Even in India, however, the majority of these universities have not successfully copied the U.S. model (Brass, 1962). They make an important contribution to agricultural development by providing bachelors and masters level degrees, but they do little research and produce few scientists.

In the other five countries of this study, government research institutions were never integrated with the universities. Today the faculty of many agricultural universities have little contact with research scientists. The Minnesota teams that visited Pakistan and Indonesia and the recent evaluations of the Bangladesh system (Anderson et al, 1983) all emphasized the need for closer ties between research institutions and universities. In the Philippines, Bangladesh, and Pakistan, most scientists with Ph.D.s are located in universities but in Bangladesh and Pakistan they are producing very little research.

AID has financed a number of projects that have tried to get faculty more involved with research. In the Philippines PCARRD provided money to principal investigators of PCARRD financed projects. The Bangladesh Agricultural Research Council is encouraging joint research projects which use scientists from the

agricultural university and other research institutions. The National Coordinated Research Programs of the Pakistan Agricultural Research Council brings together scientists from universities and research institutions.

Important problems remain in this area. Faculty members frequently have such heavy teaching and administrative responsibilities that it is not possible to do research. Money for research may not be available and even if it is there is no arrangement to buy off some time from the university. Promotions may be determined by factors other than research so there is no incentive. In spite of these problems some scientists at these universities continue to do research. It is important that AID assist them when possible.

The Relationship Between Farmers and the Research System

There are several ways that institutions link researchers with farmers. Individual scientists may have farms themselves, have family ties with farmers or have contact with some farmers directly in their work. Extension agencies provide a link between farmers and researchers. Private and public agribusiness provides information and new technology to farmers and can inform scientists of their customers' needs. Merchants who purchase and process agricultural commodities or sell agricultural inputs can inform scientists of farmers' needs and farmers about new technology. Farmers' organizations and political parties can also be a source of information to researchers about what farmers want. Farmers' organizations are often means of diffusing new technology. These linkages have three main functions: to spread new technology to farmers; to communicate farmers' needs to scientists; and to build client support for the research system.

AID projects have affected these linkages in several ways. AID increased the supply of extension staff. In the 1950s AID invested heavily in active

extension systems in countries in Asia. In the 1960s the university building projects increased the supply of manpower and upgraded the quality and size of extension bureaucracies. In the 1950s and 1960s AID financed institutional changes to bring research and extension closer. It was most successful in India where several of the agricultural universities were able to integrate research, extension and education. In the 1970s and 1980s AID and the World Bank have divided projects. AID built the research institutions and the Bank financed the extension systems and the linkages between research and extension. Farming systems research is an institutional change financed by AID which has brought scientists and farmers into closer contact. In addition, some recent AID research projects like the BARC project in Bangladesh provide funds for improving communications and public relations for the research system.

Other changes in these linkages were inadvertent by products of AID activities which had other goals. AID wanted to gain autonomy for certain research institutions and in the process split these institutions from the extension services to which they had been attached. Upgrading researchers' salaries increased the differences between researchers and extension agents. These changes have increased communication problems and in some cases have increased the competition between research and extension for funds. AID's assistance and pressure to privatize the input supply industry has induced some private research, but its main effect has been to induce private companies to spread new technology. Finally, because a large part of agricultural research is funded by donors, scientists' incentive to develop linkages between research and extension has weakened. Until recently the donors have had little ability to monitor the impact of research on farmers so they could not assess whether the research was useful or not. Therefore, in the past the donors provided little incentive for practical research.

AID's major initiative in the area of farmer-scientist linkages at present is farming systems research. The Indonesian cropping systems program is the oldest. It developed out of the agronomy (multiple cropping) activity of CRIA in 1971 and then was supported by the GOI/IRRI/USAID rice research project (IRRI, 1982: 15). It has had several successes in developing new practices which have spread to farmers. For example, management techniques were developed which allow stable food production on some of the most infertile soil in the outer islands. After the introduction of short duration HYV's, the farming systems program showed that in Java an extra crop or two could be grown by direct seeding and use of early maturing varieties. This cropping systems program has also influenced research priorities. It showed that new varieties of palawija (upland) crops were needed for the new cropping patterns. The project hired a breeder for legume development, sent people for training on this topic and eventually initiated a large breeding program on palawija crops (IRRI, 1982:19).

Elsewhere are examples of problems which farming systems identified that otherwise would have remained unnoticed for some time. In Bangladesh BRRI's cropping systems program helped identify zinc deficiency as a significant problem. This led to a research program to determine the most efficient way to overcome the problem (Hobbs, personal communication). Farming systems in the Philippines had some success introducing new technology. Evenson, et al (1981: 32) report the KABSAKA project has been successful in increasing farmers' income by convincing them to grow two rice crops instead of one.

To judge the impact of AID assistance in this area it is important to know whether it improved the flow of information to the farmer, improved the flow of information to scientists, or improved the political support of the research

system to ultimately increase the incomes of farmers and consumers. The direction of most of the changes supported by AID is quite clear but the magnitude of the impact is less clear. More extension agents and better trained agents are likely to increase the spread of new technology from research. Closer institutional linkages between extension and research should mean better communication and more incentive to work cooperatively to provide services and generate support while less linkage means less communication and incentives. More private sector input supply and less government should mean improved spread of new technology and should provide another source of support for research.

The impact of farming systems research is yet not clear. Farming systems research has been successful in forcing some scientists into farmers' fields. Its impact on setting priorities of the research system or generating political support is not obvious. Farmers often have no political clout. Scientists can ignore recommendations from farming systems research without suffering serious consequences. Furthermore, it is not clear that FSR as it is being carried out in many countries is the most cost effective way of collecting data with which to set priorities or test and extend new technology. Earlier constraints studies were a cheaper and perhaps equally effective means of setting priorities and farm trials can be carried out effectively in a number of different ways. A study is needed to compare the cost effectiveness of some FSR projects with the effectiveness of more conventional programs.

Recommendations

AID's goals are to assist in the development of self-sustaining national research systems which help increase the productivity of the small producer. Official AID documents as well as the discussion and actions of AID officials support such a goal. The 1982 AID Policy Paper on Food and Agricultural

Development (May, 1983) states that one of the four major elements of this policy is to "develop human resources and institutional capabilities especially to generate, adapt, and apply improved science and technology for food and agricultural development.." (p. 2). AID recognizes as "particularly vital" national institutions that give a country the capacity (1) to generate and apply a continuing stream of innovations designed to increase agricultural productivity and incomes; and (2) to evaluate and adapt technologies transferred from developed countries and international institutions." (p. 4). The report also notes that "section 103A of the Foreign Assistance Act requires that agricultural research carried out under the Act take account of the special needs of small farmers in setting research priorities, as well as support research on the various factors affecting small farmers, and emphasize field-testing and research dissemination."

We have argued that the long-run viability of the research system depends on the emergence of organized producer groups who are effective in bringing their interests to bear on the legislative and executive budgetary processes. The support of finance and planning ministries for agricultural research is undependable. Their support tends to fluctuate with the perceived severity of food crises and foreign exchange demands. We have also argued that without the pressure from producers who control budgets, research systems have less incentive to be efficient and less incentive to develop effective linkages with farmers through extension and on-farm research programs.

In our judgement underinvestment of local resources in research and cycles of development and erosion are inherent in the traditional project approach to research capacity development. The reason for this inherent contradiction is that external assistance provides an alternative to the development of domestic political support for agricultural research. National research system directors

have frequently found that external support requires less intensive entrepreneurial effort than the cultivation of domestic political support. Domestic budget support required by donors is often achieved by creative manipulation of budget categories rather than by increments in real program support - particularly when donor representatives are under pressure from assistance agency management to "move resources." Most existing project systems have built-in incentives for national research system leadership to direct entrepreneurial effort toward the donor community rather than toward the domestic political system.

Any effective alternative should attempt to reverse the perverse incentives that characterize existing development assistance instruments. The system should be changed to provide incentives for national research system directors to redirect their entrepreneurial efforts toward building domestic political and economic support for agricultural development.

What alternatives to the existing system do we suggest? We do not want to be interpreted as completely negative with respect to traditional development assistance instruments. Project aid is often appropriate for physical infrastructure development projects. Program aid can be an effective way to provide macroeconomic assistance for structural adjustment or for sector development in a country with substantial capacity for macroeconomic policy analysis and program management.

Neither the traditional program aid nor project aid instruments are, however, fully effective in countries that have little financial or professional capacity for providing support for long-term institution building efforts. New methods of combining the flexibility of program support, effective technical assistance, and sustained financial support for long-term research development efforts must be sought. One innovation that might be used effectively is for

the donor community to move toward an approach in which the amount of external support is linked to growth in domestic support. This implies the development of a "formula" approach in which the size of donor contribution would be tied to the growth of domestic support. The formula should include a factor that adjusts the ratio of external to domestic support to take into account differences in domestic fiscal capacity. An illustration of how such a formula finding might work is presented in Table 5.3.

A second alternative might take its lead from the experience now accumulated with the CGIAR model and the various donor consortia that have been organized to coordinate assistance to some of the larger aid recipients. What I am suggesting here is country level Research Assistance Support and Implementation Groups (RASIGs), chaired by the chairman of the National Agricultural Research Council or the director of agricultural research. The support group would need to have relatively long-term program plans for the development and operation of the national agricultural research system. To produce and continuously update this program, the national research system may require external assistance, but in general the program should be the product of indigenous experts in agricultural science and development. Its focus, to help protect the program from vagaries of political change, would be on long-term agricultural research needs and goals and on the incremental steps required for implementation.

It is expected that long-term program development and priority setting would be done through an interactive process with the support group. Once the program has been accepted, donor members of the support group, it is hoped, would collectively agree with the host country to help provide the components essential to the execution of the program as a whole. The host country, in turn, would assume the responsibility for moving its national research program along the agreed-upon development path. Initial commitments might be for three

Table 5.5 Illustration of a Funding Model for Agricultural Research Support

National Fiscal Capacity	Program Support and Assistance Level (in millions of U.S. $)					
	Low		Medium		High	
	National Support	Donor Assistance	National Support	Donor Assistance	National Support	Donor Assistance
Low (40% Assistance)	20	8	50	20	100	40
Medium (20% Assistance)	20	4	50	10	100	20
High (10% Assistance)	20	2	50	5	100	10

to five years subject to annual review and course corrections suggested by the analysis and feedback from actual experience.

Use of an institution such as a support group has the potential of helping the country involved avoid many of the pitfalls of the project mode while retaining several of its desired attributes. Donor identity could be retained by relating grants to components of the agreed-upon overall program. These could even be called projects if so desired for administrative purposes. The support group, like the CGIAR, would likely involve bilateral grants developed in the framework provided by the forum of multiple donors and the host country.

These support groups also has several other potential advantages. First, it would contribute to building a national constituency by focusing from the onset on this essential ingredient for viability. The donors, for example, might agree to increase their contributions by some fraction of the rise that occurred in the real support provided by the nation involved. Other matching provisions might be agreed upon to provide incentives for nurturing and cultivating national constituencies. Second, it would provide reasonable continuity in support (commitments would be fairly long-term and subject to review and extension well in advance of termination dates) with less risk of the excessive program fragmentation frequently associated with narrowly defined project funding. Third, it would reduce the administrative and management load on the host country through the planning and review process the support group would follow. Fourth, it would place donors in a position of genuinely complementing and supplementing one another and the national program rather than endlessly competing for "good investment opportunities."

If AID does continue to operate in the project framework we recommend, the following for AID's consideration:

Recommendation 1: Where AID cannot change from the project approach it should design research projects that are long term, contain as much flexibility as possible to meet both political and economic needs and are evaluated on the basis of their success in generating local political support as well as meeting farmers' needs.

Recommendation 2: AID still needs to fund research projects on the major foodgrains in Nepal and perhaps Bangladesh and Pakistan. Research on some of the major inputs like land, water and fertilizer are potential areas for investment in most of these countries. Food policy research is another area with potentially high payoffs in all of these countries with the possible exception of India in which considerable policy research is already being done. Plant and animal protection is another area for expansion of AID's support.

Recommendation 3: It is important to decentralize the research systems of large countries. This will make the research system more efficient and it will help the research system develop political support. AID should continue to support this activity in Bangladesh, the Philippines, Pakistan and Indonesia.

Recommendation 4: AID should look for ways to strengthen graduate education in agriculture both through investments in human capital, facilities and research projects at universities and the development of closer relationships between agricultural research institutions and universities.

Recommendation 5: AID should continue to invest in the International Agricultural Research Centers. In all countries with the possible exception of Thailand (where Rockefeller Foundation pre-empted the IARCs) we found evidence that the Centers have had a major impact on the research system and farmers. Now that the physical infrastructure of the national systems has been developed and scientists have been trained, the seminars, networks and germplasm collections of the Centers will be more productive than ever. The Center's activities

will be particularly important for the small countries of Asia which cannot afford to have a large research system of their own.

Recommendation 6: AID should do what it can to encourage private companies and commodity organizations to do more research and to provide more support for government research. AID might provide resources to subsidize such research in its early stages. In addition AID might provide policy advice regarding the impact of government enterprises, patents, regulations, taxation and other activities on private sector research.

Chapter 5

Anderson, Jock, Kim W. Bridges Oleen Hess and Carl E. Pray (1983), Agricultural Research Project II: Report of the May External Evaluation Team, Dhaka: Bangladesh Agricultural Research Council.

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Appendix I*

An Economic Perspective on Supply Growth

Figure 1 provides an overall perspective on the economics of agricultural supply. It depicts three basic components. The central component is the model core. It consists of equations which describe the behavior of farm producers as they attempt to maximize profits. This behavior produces farm land output or product supply functions and input or factor demand functions. The factor markets and the product markets are the remaining two components of the larger model.

The factor markets have a demand side which is the aggregated factor demands by farmers. The supply side of these markets is derived from various sources. Labor supply is based on population growth, on migration between rural and urban sectors and between regions and on the basic labor-leisure choice that individuals make. The supply side of the mechanical power and farm chemical markets is determined by the cost structure in these industries. Animal power supply is determined by food costs on the farm. Land may be fixed in supply, but improved land is not. Irrigation and other land improvements can increase its supply.

The agricultural product markets have a supply side which is the aggregated output supplies of individual farm units. They have a demand side determined by the number of domestic consumers, their incomes and tastes and prices. For some commodities an international demand exists. For others, an international supply to be added to domestic farm supply exists.

Each of the factor and product markets will be in equilibrium when markets clear, i.e., when no excess demand or supply exists. Equilibrium in this sense

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* This section is quoted from Evenson, 1983.

is not inconsistent with having public agencies or private firms hold commodity stocks in inventory. It is also possible that the costs of searching for and migrating to jobs is such that considerable apparent unemployment is consistent with equilibrium as well. This equilibrium will consist of an equilibrium set of outputs, output prices (relative to a numeraive bundle of non-agricultural goods prices), factor employments and factor prices.

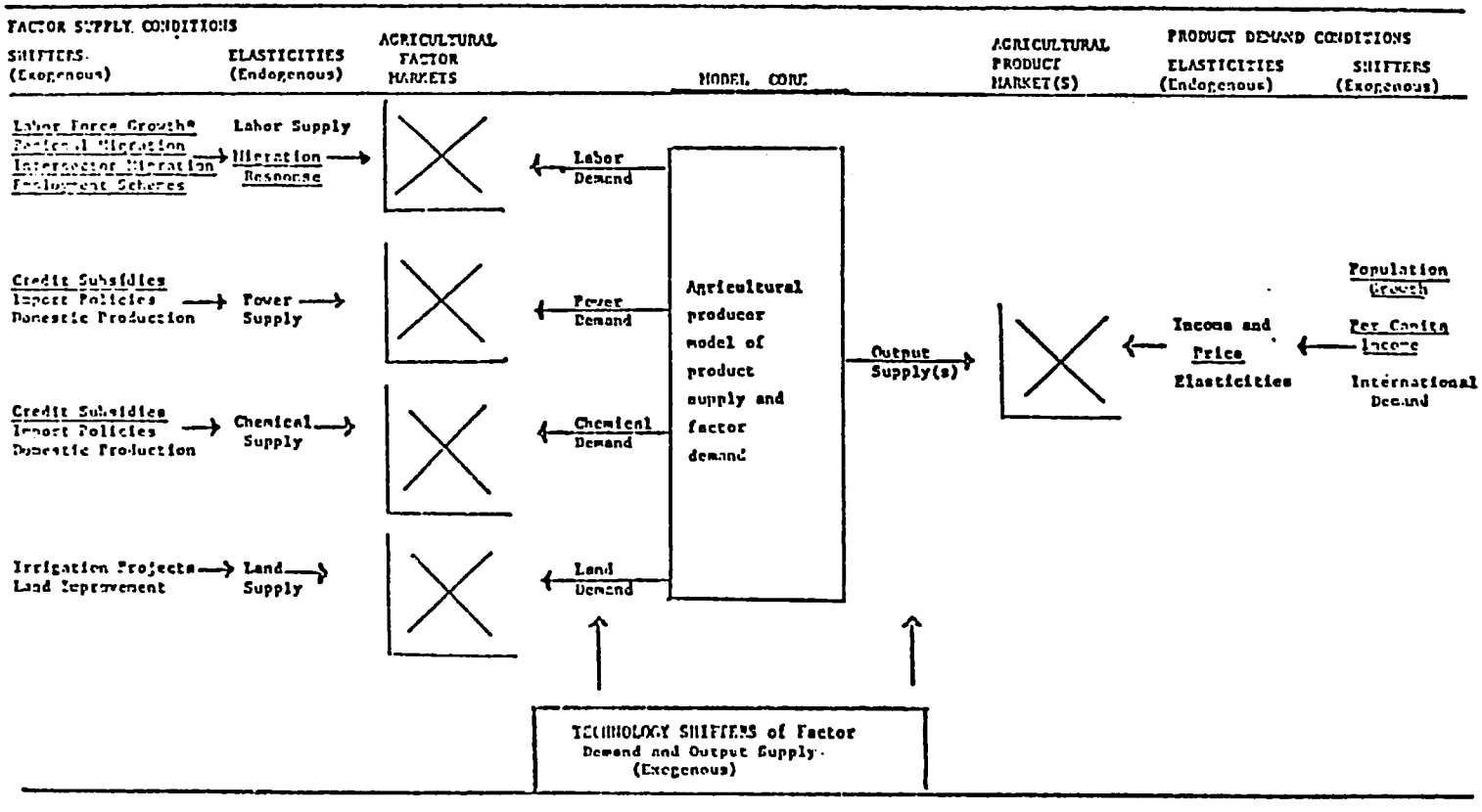
The items described as "shifters" in Figure 1.1, are factors which shift one or more of the supply or demand functions in the model. Each shift will then produce a new equilibrium of all outputs, factors and prices. Shifters are grouped according to whether they shift output demand functions (population growth, income growth, trade policy); factor supply functions (labor force growth, nonfarm employment demand, credit and trade policies); or the technology of production.

Equilibrium output supply will change in response to these shifters. Other endogenous variables in the model will also change. We are particularly interested in those shifters which affect the factor markets and the technology shifters. Technology shifters are embedded in the model core.

In the empirical work on India I specify a system in which farmers choose among four variable crops of crop combinations; rice, wheat, coarse cereals (corn, sorghum and millet) and other crops (pulses, sugar, cotton, etc.).

This work also employs four variable factors of production which are fertilizer, animal power, tractors and labor. The structure of these farms (i.e., the factors over which the individual farm has little or no control in the short run) is measured by the degree of rural electrification, investment in roads, rainfall and climate, irrigation investment, net cropped area, and the availability of new technology as measured by the proportion of area planted to high yielding varieties and past investment in agricultural research and extension.

Figure 1.1 Distributional Policy Analysis Model: Schematic Representation



Note: The core model and underlined items will receive particular emphasis in estimation and policy simulation

The theoretical basis for deriving the core relationships rests on the "duality" between maximized profits and the technical transformation function relating the four variable outputs to the four variable factors and the structure variables. When certain restrictions hold for the maximized profit function, duality theory insures that they also hold for the transformation function. The important thing about this fact is that we can specify a functional form for the maximized profits function directly. This is much simpler than specifying a functional form for the transformation function and "solving" for the maximized profits function. The maximized profits funtion does not include any choice or endogenous variables. Most importantly, however, we can apply the Hotelling-Shephard lemma which states that the first partial derivatives of the maximized profits function with respect to an output or factor price are the output supply and factor demand functions. Thus, by taking eight partial derivatives, we end up with a system of four output supply functions and four factor demand equations. Each equation relates the quantity supplied (or demanded) to the eight variable prices and the structure variables.

Appendix II

List of Publications

A. Unpublished Papers and Reports:

Boyce, James K., "Agricultural Research in Indonesia, the Philippines, Bangladesh, South Korea and India: A Documentary History," Mimeo.

Evenson, R.E. and S. Setboonsarng, "Research, Extension, Literacy and Productivity Growth in the Agricultural Sector in Thailand," Mimeo, Department of Economics, Yale University, 1984.

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Quizon, J. and R.E. Evenson, "Distributional Price and Income Consequences of Agricultural Technology in the Philippines," Mimeo, Department of Economics, Yale University, 1983.

B. Ph.D. Theses:

Nagy, Joseph G., "The Pakistan Agricultural Development Model: An Economic Evaluation of Agricultural Research and Extension Expenditures," Ph.D. Thesis, Department of Agricultural and Applied Economics, University of Minnesota, 1984.

Salmon, David, "An Evaluation of Investment in Agricultural Research in Indonesia, 1965-1977," Ph.D. Thesis, Department of Agricultural and Applied Economics, University of Minnesota, 1984.

C. University of Minnesota - Economic Development Center Bulletins, 1980-1983:

Bulletin Number 81-1, Vernon Cardwell, James C. Moomaw, and Vernon W. Ruttan, "Agricultural Research in Indonesia," March 1981.

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Bulletin Number 82-2, M. Prahladachar, "Income Distribution Effects of Green Revolution in India: A Review of Empirical Evidence," April 1982.

C. UMEDC Bulletins 1980-1983 (continued):

Bulletin Number 83-1, David C. Salmon, "Congruence of Agricultural Research in Indonesia 1974-1978," January 1983.

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UMEDC (reprints) 82-2, Carl E. Pray, "The Green Revolution as a Case Study in Transfer of Technology," November 1981.

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D. Reprints:

J.G. Nagy, "Estimating the Yield Advantage of High Yielding Wheat and Maize: The Use of Pakistani On-Farm Yield Constraints Data," The Pakistan Development Review, Pakistan Institute of Development Economics, Islamabad, 23(3), Autumn, 1983.

Joe Nagy, "Pakistan's 1977-78 Wheat Rust Epidemic: Consequences and Issues," submitted to The Pakistan Development Review, 1985.

Carl E. Pray, "Underinvestment and the Demand for Agricultural Research - A Case Study of the Punjab," Food Research Institute Studies Vol. XIX, No. 1, 1983.

Vernon Ruttan, "The Global Agricultural Support System," Science, 7 October 1983, Volume 222, p. 11.

Vernon Ruttan, "Reforming the Global Agricultural Support system," in Issues in Third World Development by Kenneth C. Nobe and Rajan K. Sampath (Westview: Boulder, 1983).

David Salmon, "Rice Productivity and Returns to Research in Indonesia," submitted to Indonesian Studies.