PN-ABS-725

Report Number 1

March 1987

ECONOMIC DEVELOPMENT CENTER

PRIVATE SECTOR AGRICULTURAL RESEARCH AND TECHNOLOGY TRANSFER IN LDCS: REPORT ON PHASE II

Carl E. Pray

ECONOMIC DEVELOPMENT CENTER
Department of Economics, Minneapolis
Department of Agricultural and Applied Economics, St. Paul

UNIVERSITY OF MINNESOTA

Private Sector Agricultural Research and Technology Transfer in LDCs: Report on Phase II

by

Carl E. Pray

PN-20

93 000 91

Department of Agricultural Economics
Cook College, Rutgers University
New Brunswick, New Jersey 08903

March 2, 1987

The research upon which this report was based was supported by the U.S. Agency for International Development (Contract No. OTR-0091-G-SS-4195-00).

The University of Minnesota is committed to a policy that all persons shall have equal access to its programs, facilities, and employment without regard to race, religion, color, sex, natural origin, handicap or veteran status.

Executive Summary

This is final report of the second phase of the Private Sector Agricultural Research Project. The results of the first phase are reported in Pray (1985). The purpose of the second phase of the project was to: (1) find out how important private sector research and technology transfer is in the Third World; (2) identify important policies that constrain or induce companies to invest in R&D; (3) survey AID and International Agricultural Research Center's policies which influence private agricultural research; and (4) in preparation for phase three of this project, identify regions and commodities in which it may be possible to quantify the impact of private research and technology transfer and quantify the effect of policies which constrain or induce research.

The main sources of information for this phase of the project were personal interviews; published and unpublished reports collected in Asia; and international production, trade and input data from the FAO and USDA. The interviews were conducted in eight countries during the period March 1985 through February 1986. The countries were India, Bangladesh, Pakistan, Philippines, Thailand, Indonesia, Malaysia and Singapore. The representatisves of approximately 100 firms were interviewed.

The data indicate that the private sector is playing an important and growing role in supplying new technology to farmers. Research expenditure is quite large in some countries – about $17 million in India and perhaps $10 million in Malaysia. The trend in expenditures is upward although some countries like the Philippines have suffered declines in recent years. While these investments are important, they are not large amounts compared

to government investments in research in these countries or private sector research in Japan and the West. The research conducted by these firms goes fromgenetic engineering to simple replicated trials of new crop varieties or new chemicals. The bulk of the research is at the applied end of the spectrum.

The study found evidence that government policies can be an important determinant of private sector investment in research and technology transfer. Little private sector research will take place unless the basic infrastructure for modern agriculture is in place. This requires public investment in infrastructure like public research, extension, education, transportation, communication and irrigation. In addition, the government must allow the private sector to play an active role in supplying modern inputs and processing agricultural products. If these conditions are met, government science and technology policies can be used to induce more private research investment.

We identified the seed and pesticide industries as two industries in which private research and technology transfer has had a significant impact on agriculture. The seed industry has produced hybrids that are used on several million hectares in Asia, and farmers buy more than half a billion dollars worth of pesticides each year. Research by the plantation industry has probably had more impact on agricultural output. However, studies of the policies that affect the seed and chemical industries may have implications for a wider range of countries that the plantation industries and so we hope to examine these industries in Phase III.

Developing Country Policies

The following policy suggestions appear to be justified on the basis of the preliminary evidence that we have gathered. An important caveat is that the policy emphasis of governments must change with levels of development.

1. Countries should eliminate laws or regulations that prohibit private research.

2. Companies must be allowed to commercialize the products they develop through resesarch of technology transfer.

3. Investment in public sector agricultural research is required at all stages of development. Public research must change with development. As the private sector develops, public research can shift their focus to poor people's problems and more basic research which supports private sector research.

4. In countries where the private sector is more developed, special incentives for private research like tax incentives and more effective patents may be effective in inducing companies to invest in more research.

5. The most important input into R&D and techn;ology transfer is scientific manpower. Therefore governments must invest in higher education and financing scientists for overseas training.

6. Technical support from government research organizations can encourage more private innovation - particularly by local industries. For example, in the 1960's, advice by scientists from the Indian Council of Agricultural Research and the Rockefeller Foundation was important

in establishing the research programs of several Indian seed companies.

AID Policies

In each country, AID should assess the extent to which there is a private sector industry in existence which might make profits from private research. If such industries are not in existence, then they should place their emphasis on helping to develop those industries. If infrastructure is needed, AID must help develop it – there are no short cuts to the development of basic infrastructure. If policy changes are needed, then AID may be able to persuade the local government through well researched studies that change is needed or in a few cases, AID may have sufficient political clout to force changes (or include them in a World Bank/IMF structural adjustment package). If there is a private sector which could make profits from R&D or TT, then AID should be looking at the specific technology policies.

AID projects should support public sector research at all stages of development represented by the Asian countries in this study. AID support for higher education also is important for the development of private research.

AID should continue to support the CGIAR and some of the other international agricultural research organizations. They help build public research which is necessary for private research and they provide some direct support for private research.

AID needs to support more research and information about which science and technology policies work and which do not. There is not enough information to draw sound conclusions about the efficacy of many policies

that have been suggested and are being tried.

Contents

1 Introduction and Methodology **1**

2 Private Sector Research **3**

3 Determinants of Private Sector Research and Technology Transfer **12**

3.1 Determinants of Aggregate Expenditure 13

3.2 Research by Industry 16

3.3 Summary of Government Policies and their Impact on R&D 21

4 Impact of Private Research and Technology Transfer **26**

5 Preliminary Policy Suggestions for LDC Governments and AID **31**

5.1 LDC Policies 31

5.2 Current AID Activities 36

5.3 AID Policies For the Future 41

List of Tables

1 Private Sector Research Expenditure, 1985. 4

2 Philippines Private and Public Research by Commodity. . . 11

3 Possible Determinants of Private Agricultural Research. . . 14

4 Policies Affecting Private Research. 23

5 Current AID Activities Effecting Private Sector R&D in Asia 38

1 Introduction and Methodology

This is the final report of the second phase of the Private Sector Agricultural Research Project. The results of the first phase are reported in Pray (1985). The first phase consisted of a review of the literature on the economics of research and technology transfer, interviews with American multinational firms who are active in Asia and interviews with officials at AID, The World Bank, OPIC and other government organizations.

The purpose of the second phase of the project was to (1) find out how important private sector research and technology tranfer is in the Third World; (2) identify important policies that affect private research and technology transfer; (3) survey AID and IARC policies and projects which affect the private agricultural research and technology transfer, and (4) identify possibilities for quantifying the impact of private sector research and technology transfer in a third phase of this project.

In this study, the private sector means for-profit firms and excludes non-profit organizations and collective activities of for-profit companies. This study was also limited to R&D on production agriculture and excludes R&D on post harvest operations.

The main sources of information for this phase of the project were personal interviews, published and unpublished reports collected in Asia and analysis of international production, trade and input data from the FAO and USDA.

We visited eight countries during the period March 1985 through February 1986. The countries were India, Bangladesh, Pakistan, Philippines, Thailand, Indonesia, Malaysia and Singapore. The first six countries were

the main countries of interest. The brief stop in Malaysia was to visit with some of the main plantation companies which transfer technology throughout Southeast Asia. In Singapore, we visited some the regional headquarters of some multinationals for a few days. In each country, scientists and managers of the major companies conducting R&D were interviewed. We also met with government scientists and officials, USAID personnel and, in some cases, World Bank staff. Some time was spent in each country collecting available literature and data sets.

The methodology for collecting the data in this study was to visit the countries and talk to as many private companies conducting research or transferring technology as possible. A total of about 100 local firms and subsidiaries of foreign firms were interviewed. The interviews were usually with the head of R&D, but often they were with the managers or Chief Executive Officers. The interviews consisted of open ended interviews around four basic questions: (1) What research and technology transfer does the firm do? (2) What has been the impact of their research and technology transfer activities on farmers and consumers? (3) What government incentives or constraints influence their research and technology transfer activities? (4) What contact have they had with AID or other donors?

In Bangladesh, Pakistan and Indonesia where there was little private sector research, almost all firms that had formal research programs were contacted. In India, the Philippines, Thailand and Malaysia a sample of firms were interviewed. This was not a random sample, rather it was the firms in which we had contacts. The sample may be biased by over sampling the multinationals and undersampling the local firms. We did, however, make special efforts to contact at least one local firm in each industry.

We also collected FAO and USDA data on technology transfer in the seed and pesticide industries and conducted some preliminary statistical analysis to find out what the production impact of technology transfer has been. This data was worldwide rather than being restricted to Asia as the interviews were. We also reviewed case studies of private R&D from Argentina, Brazil, Ecuador, Venezuela and Kenya which were conducted under the auspices of ISNAR.

Finally, we visited IRRI, ICRISAT, ISNAR and collected information on other centers through interviews with staff members and participation in the Impact Study of CGIAR.

2 Private Sector Research

Our best estimates of private sector research are presented in Table 1. They are based primarily on our survey and supplemented by published data where available. They are almost certainly underestimates because it was not possible to interview all companies conducting resesarch in most countries. In Malaysia in particular, we only had time to interview a few firms and most of those were in the plantation sector in peninsular Malaysia.

Table 1. Private Sector Research Expenditure, 1985.

	India	Philippines	Thailand	Indonesia	Malaysia	Pakistan	Bangladesh	Total
			(US$ 1.000s)					
Seeds	833 (8)[a]	1583 (4)	665 (5)	0	0	182 (3)	Less than 1000 (1)	3264
Pesticides	3500 (20)	1170 (8)	887 (5)	800 (1)	500 (3)	387 (5)	40 (2)	7284
Machinery	6775 (3)	none	none	none	?	none	none	6775
Livestock	2275 (3)	500 (6)	1725 (2)	600 (3)	?	none	none	5100
Processing and Plantations	3324 (25)	1137 (7)	1034 (3)	600 (3)	10000 (9)	234 (2)	50 (1)	16379
Total Private	16707	4390	4311	2000	10500	804	90	38802
Government Ag. R & D	248000	7000	48274	62000	44400*	29899*	28910	
Private as Percent of Govt. Research	7	63	9	3	24	3	0.1	
Agricultural Value Added ($ billions)	59.7	8.7	5.6	21.2	6.6	6.6	6.7	
Private R&D as Percent Ag. GDP	.03	.06	.05	.01	.17	.01	.00	

[a]Number of firms in parentheses.

[b]1980 expenditures.

Sources: Private sector from interviews. Government R & D; India. Philippines, Sardido unpublished data.

The amount of private sector research is large relative to previous expectations. Most policy makers and government scientists thought private research and development was almost nonexistent in South and Southeast Asia. The amount of private research is small, however, when compared with private research in developed economies like the U.S., the size of Asian agricultural sectors or the size of public sector research expenditures in Asia. The latest survey of agricultural research in the U.S. (ARI, 1986) suggests that U..S. private firms spend at least $2.1 billion on agricultural research. The mean expenditure on R&D of the 356 companies in the survey was $3.8 million which is more than is spent by the private sector in Indonesia, Pakistan and Bangladesh put together. Private research expenditure as a percent of agricultural value added was less than 0.2 percent in all countries sampled (see Table 1). In comparison, the U.S. spent 2 percent of agricultural GDP or 3 percent of value added. In the sampled countries, the public sector spends far more on agricultural research than the private sector. Table 1 indicates that the Philippines is the only place in which the private sector spends as much as a third of the total research expenditure of the country.

Across all seven countries, the most research was carried out by the plantation and processing industries.[1] This category includes oil palm millers and planters, rubber planters, cigarette manufacturers, banana growers and exporters, sugarmillers, pineapple canners and producers and a few others. It should be noted that almost two-thirds of the plantation research is done in Malaysia. The ownership of the Malaysian companies is by a mixture

[1]These industries are in the same category because many processing companies like oilmills or sugarmills also have large plantations to supply these mills.

of government owned corporations, local private companies, American and European based multinationals and Asian based multinationals. Some of the largest plantations are not entirely private. They have been purchased recently by the public sector but are still operated as private corporations.

The research of processing and plantation firms spans a wide spectrum. Plant breeding and selection is done by oilpalm plantations, rubber plantations, pineapple processors and cigarette companies. Several companies are using sophisticated tissue culture techniques to clone and multiply oilpalms, and at least two companies are doing research to develop techniques to clone coconuts. Plantation and processing firms invest a lot of money in reducing their plant protection costs. Plantations in Malaysia and Indonesia are doing or are financing biological pest control research and integrated pest management research. Research in the Philippines is attempting to reduce the cost of plant protection on banana plantations and to identify safer pesticides and application techniques.

There are major investments in research by the input industries. Pesticide research is dominated by multinational companies. India is the only place where local companies are doing much R&D. The multinationals conduct centrally funded research in Asia that tests new compounds and methods of applying pesticides. Local subsidiaries fund testing of new chemicals, formulations and application techniques and perform tests required for registration. The only country in which there was some synthesis of new compounds was in India, and the two companies that did some synthesis research have probably stopped in the last few years. Bioefficacy and registration research is carried on in every country, but there is a tendency for centrally funded research to concentrate in a few countries where regional

stations are located. The Philippines has five regional programs for rice and Malaysia five or six for plantation crops.

Regional and local research by chemical companies consists of screening new compounds in field tests after they have passed all of the basic toxicity tests and the initial greenhouse screens back at headquarters. Among the new products that are being tested now are insect growth regulators such as chitin inhibitors some of which have recently come on the market. Companies also try compounds that are already being used commercially somewhere in the world on different pests and in new ecological conditions. In all, seven countries covered by this survey companies are required to prove bioefficacy in local conditions. There is some research on improved application methods. There is a small amount of private research on integrated pest management (IPM). Some of this is done by plantations or in cooperation with plantations. Other IPM research is done on cotton and vegetables as a result of the build up of insect pests which are resistant to most pesticides.

Most of the pesticide research is on insecticides for use in rice and cotton. There has also been considerable research on herbicides for plantation crops. Recently, there has been increased emphasis on rice herbicide research for Southeast Asia, rice fungicides and wheat herbicides for South Asia.

Formal R&D on agricultural machinery is primarily by a few large firms in India which do research on tractors and pumps. The tractor firms concentrate on improving fuel efficiency and increasing their safety for road use because haulage is the major use of tractors in India. Pump manufacturers are trying to increase the efficiency of their pumps, and at least one company is trying to develop solar powered pumps.

There is a lot of informal research on farm machinery being done in all of these countries. Recent studies on the Philippines (Mikkelson, 1984), Thailand (Paitoon, 1982) and Bangladesh (Jabbar, 19XX) substantiate the large amount of innovative activity and indicate that this activity had some impact on production. However, because of the short time of our surveys, we could only interview a few small firms in order to corroborate the findings of other studies. The research in this sector was primarily trying out suggestions by farmers for improved machinery or changes to make production cheaper by substituting cheaper inputs for more expensive ones.

Livestock research includes poultry breeding by one firm in India, swine breeding by a Thai firm and a lot of research on feed composition and productionby a number of firms in India, Thailand and the Philippines. Feed research is done mainly by Asia firms, but some is carried out by multinationals. Feed research concentrates on improving quality and reducing the cost of poultry feed. Several companies are also doing research on ways of producing shrimp cheaply for export.

The Philippines has the most research expenditure by the seed industry. This is largely due to Pioneer's large program in Mindinao which serves Indonesia and Thailand as well as the Philippines. Multinationals play a very large role in this research in the Philippines, Thailand and Pakistan but not in India where several local companies have research programs.

Seed research concentrates on breeding hybrid corn with some breeding work on hybrid sorghum, sorghum-sudan grass, sunflower and pearl millet. There is also a small amount of research on hybrid rice. A few companies have some research on plant protection, agronomy and plant physiology.

One category of research which is not shown in Table 1 but which is of

considerable interest to companies and policy makers in Asia is biotechnology research. Research using the new biotechnology techniques is being carried out by some companies in Asia. In addition, a number of multinational companies that are using these techniques in their corporate laboratories have subsidiaries in Asia.

At least one company in this region in India – Hindustan Lever is doing some research using genetic engineering. It is working on the production of vegetable oil by splicing genes of single-celled yeast to try to produce oil commercially in an industrial process.

At least four companies are involved in tissue culture research. They are the Indian company that is doing genetic engineering, Plantek in Singapore, and some plantation companies in Malaysia and Indonesia. The research on cloning oilpalms and coconuts by Unilever and Harrisons was mentioned in the plantation section. In addition, Sime-Darby is doing tissue culture research on oilpalm in Malaysia. Socfindo and a French firm are working on oilpalms and coconuts in Indonesia, and Plantek is working on plantation crops of various types.

An even larger number of companies are working with products which are called plant growth regulators, plant growth nutrients, or even natural fertilizers in some cases. Some of these products are supposed to enhance photosynthetic activity. Others are supposed to stimulate microbiological activity in the soil so that more nutrients are available to the plant. There is also research to select more productive strains of nitrogen fixing bacteria. Applied research to test threse products in different environments is being conducted in Asia. Much of this research would not qualify as new biotechnology research.

Several companies are also working on feed additives which they claim to be new biotechnology. At least three multinational chemical companies are testing insect growth regulators and at least one company is working to select more effective strains of *b. thuringensis*. Some of these products might be legitimately categorized as new biotechnology in that they were developed using the new biotechnology techniques. Many of these products are not new biotechnology, but simply chemicals which were producted by standard research programs.

After this list of private R&D, it is useful to also remember what the private sector does not doing. There are certain crops which the private sector will not work on. Table 2 is a rough estimate of the distribution of private and public research in the Philippines where the private sector plays a very large role. The table shows a number of crops on which the private sector spends little research money. These include important subsistence crops like yams and cassava plus white corn and unirrigated rice. This is because companies do not sell subsistence farmers many inputs and can not profit by buying the farmers' produce. There is little research in sugarcane because it is so unprofitable. The private sector also will not do much research in certain disciplines or topics. There is very little IPM research, farm management research, plant nutrition research, plant breeding research on nonhybrids or social science research by the private sector.

Table 2. Philippines Private and Public Research by Commodity
(millions of pesos)

	Private (1985)	Public (1984)
Rice	20	15
Corn	30	6
Sugarcane	3	29
Coconut	2	11
Tobacco	2	19
Fruits and Vegetables	19	3
Other Crops	3	27*
Livestock and Poultry	5	17

Sources: Private from survey; public from Sardido.

*Half of this is root crop research.

There are some regions or countries that are almost completely neglected by private sector research. Table 1 indicates that some of the least developed economies have the least private research. This is due in part to the low level of modern inputs use and small marketed surplus which means it is unprofitable for companies to do research.

Finally, it should be noted that private research in Asia is, for the most part, very applied research. It concentrates on adaptive work which allows technology developed elsewhere or in the public sector to fit local agroclimatic and economic conditions. Really basic research on plant genetics is conducted in only one or two companies in Asia, and they are multinational companies. The small amount of basic research in the private sector is a pattern that is found worldwide.

3 Determinants of Private Sector Research and Technology Transfer

The second major issue in phase II was the importance of government in determining the amount and direction of private research and technology transfer. Whether private firms will invest money in the adaptation and research required to transfer technology or whether they will invest in R&D to develop new technologies depends on the profits they expect to make from these investments. A firm's expectation about profits will depend on (1) the size of the market for the new process or product which results from research; (2) the expected profit per unit of the new products sold; (3) the cost of the research, development (or adaptation), production (or

importation) and promotion needed to bring a new product to market; and (4) government policies which affect the other three factors.

The size of market is probably the most important factor explaining the different levels of investment in research and technology transfer by the private sector. Market size is primarily determined by the size of the country, its level of modernization and level of government invention in input and output markets.

3.1 Determinants of Aggregate Expenditure

The first line of Table 3 shows our estimates of private research expenditure from Table 1. The rest of the table contains some indicators of: (1) market size - agricultural value added; (2) agricultural modernization; (3) the amount of commercialization (urbanization), and (4) government intervention. Government has affected the size of the agricultural sector and the amount of commercialization indirectly. Modernization has been due in part to government and international investments in agricultural research, extension and input supply. This estimate of government intervention is based on both the government shares of input supply and government intervention in markets through price controls. The amount of agricultural input supply and processing that is done by the public sector is, of course, a government decision.

Table 3. Possible Determinants of Private Agricultural Research.

	India	Indonesia	Philippines	Malaysia	Pakistan	Bangladesh	Thailand
Private R & D (US$ millions)	16.7	2.0	4.4	10.5	0.8	.1	4.3
Private R & D as % Ag. V.A.	.03	.01	.06	.17	.01	.00	.05
Ag. V.A. ($ billions)	59.7	21.2	8.7	6.6	6.6	6.7	5.6
Modernization							
Fert. (kg. nutrient/ha.)	34	75	29	97	57	48	19
Tractor (per 1000 ha.)	2.7	.7	1.6	1.8	6.0	.5	5.4
Cereals yield (kg./ha.)	1486	3352	1723	2647	1637	2013	1986
Commercialization Urban %	25	25	39	31	29	18	18
Government Intervention	Major	Major	Minor	Minor	Major	Major	Minor

Sources: First three rows Table 1.
Modernization and Commercialization from World Resources Institute 1986.
Government Intervention - estimates of author.

The numbers in Table 3 are consistent with the importance of market size in determining private research expenditure. India, which has the largest agricultural sector of these countries and also the largest markets for modern inputs, has the most research. Bangladesh has the least private research and is the least developed of these countries with very little use of modern inputs except fertilizer, which was until recently distributed by the government. However, the relationship between market size and research is not as strong as one might expect.

The other countries are all modernizing their agriculture and have fairly large agricultural sectors. The main determinant of the level of private research appears to be government industrial policies. Indonesia, which is the next largest agricultural economy after India, has very little private research in part because the government controls most of the input distribution and owns most of the plantations. Pakistan, which has a fairly large agricultural sector and is a large market for some modern inputs, has less private R&D than one would expect possibly because the government supplied inputs until recently and has restricted private research.

Philippines, Thailand and Malaysia have much higher levels of private research than Indonesia and Pakistan and spend a higher percentage of agricultural value added on research than India. Their economies are small than Indonesia and about the same size as Pakistan. Their level of modernization is about the same or less than Pakistan and Indonesia - they use less fertilizer than Indonesia and less tractors than Pakistan. The major factor that differentiates these countries from Indonesia, Pakistan and India is that they have allowed the private sector a major role in the production and distribution of inputs. Several additional factors are the presence

of large agricultural export sectors which invest in research, the regional research headquarters for a number of agricultural chemicals companies in each country and regional headquarters of large seed companies in the Philippines and Thailand.

3.2 Research by Industry

At the industry level, it is possible to examine the relationship between market sisze, government policies and private research in more detail. In addition, one has to look at the factors like firm sisze, market share and the structure of the industry. The rest of this section presents case studies of the development of research in the seed, pesticide, farm machinery and plantation industries.

In the seed industry, companies look at acreage under open pollinated, annual, field crops - especially corn - as an indicator of potential markets. This is an explicit criteria of multinationals for entering a new market. Multinational seed companies almost inevitably invest in research. In all of these countries except the Philippines, the initial investment in private seed research on field crops appears to have been by multinationals.[2] The sequence in which research was initiated was India in 1960, Pakistan in 1965, the early 1970's in Thailand, and 1976 in the Philippines. There are no private seed research programs on annual field crops in Indonesia, Bangladesh and Malaysia.

Although the choice of country was largely due to market size, their con-

[2]In the Philippines, San Miguel conducted research in the early 1950's but was prevented from continuing by the government in 1964. In 1976, Pioneer started their research program in the Philippines and soon afterward, San Miguel revived its program.

tinuation was determined largely to government action. The small amount of multinational research in India and Pakistan is due largely to government restrictions of the role of multinationals. Both multinationals and local companies in Southeast Asia benefitted from the Kasetsart University/Rockefeller Foundation/CIMMYT program that identified genetic resistance to downy mildew. The success of local seed companies in India and Thailand is, in part, due to the role of government research in developing improved inbreds and other technical assistance at the early stages of their development. In contrast, until recently, Indonesia and Pakistan did not allow private companies to do seed research and sell new varieties to all farmers.[3]

Pesticide technology transfer and research also followed market size. An additional factor may have been the size of other investments in chemicals which companies had made. India with large cotton and rice crops, a large mosquito control program and a chemical industry was the first place many companies transferred insecticide technology in the 1950's. The plantation economies of Malaysia and Indonesia were the natural places to introduce herbicides. Paraquat was introduced there in the 1950's. Subsidies and government programs to supply pesticides were important in increasing the demand for pesticides in most countries in Asia (with the exception of Thailand?). If the government continued to supply pesticides after the point at which farmers understood their efficacy as happened in most countries, the government became a constraint to the development of private research programs.

[3]Rafhan Maize in Fakistan could only sell the results of its research to its own contract farmers.

In countries where the private sector was allowed to play an important role in supplying pesticides, growth of local research was determined by (1) the growth of demand for pesticides in rice and plantation crops which are not grown in the West, (2) the numbers of chemicals being discovered at headquarters, (3) pest resistance to specific chemicals, (4) the growing regulatory requirements, and (5) publicity of the potential ecological and health hazards of pesticides.

According to industry estimates the largest consumer of pesticides is India ($300 million) followed by Indonesia ($100-140 million), Pakistan ($100-120 million), Thailand ($100 million), Philippines ($59-81 million), and Bangladesh ($10 million). This is consistent with the investments in research of India and Bangladesh, but the Philippines and Thailand conduct more research than Indonesia and Pakistan. The position of the Philippines is due to the location of regional rice experiment stations of four or five multinationals near IRRI. Indonesian investments are held back by the government policy of distributing 75 percent of pesticides through the government supply organization at highly subsidized prices. There is no simple explanation of the position of Pakistan research. It may be that since companies can test pesticides on cotton in the U.S., there is less need to do applied research on cotton pesticides in Asia. Private research may simply not have caught up with the rapid growth of pesticide use brought on by denationalization of pesticide supply in the early 1980's. Another possibility is political instability and the risk of future nationalization reduced the incentive to do research there.

The machinery story looks simple. India used 450,000 tractors in the early 1980's. The next largest market in our sample of countries was Pak-

istan with 120,000. With this large a market, it is hardly surprising that Indian agricultural machinery manufacturers do all of the formal R&D that is conducted in these countries. In fact, the story is probably not so simple. The government of India has had considerable influence on the amount of research through its policies on imports, restrictions on what products large companies can sell, and policies on foreign ownership and technical agreements. A more thorough time series study is required to determine how these policies influenced research in this industry.

Informal research on simpler agricultural machinery is going on continuously in all of the sample countries. The amount has grown as agricultural mechanization has grown. Some government policies have influenced the amount of innovation that has taken place. Utility patents appear to have been an incentive to research in the Philippines. Government programs in rice mechanization that were supported by IRRI in the Philippines, Thailand and Indonesia have induced innovative, informal reseasrch in these countries.

The market for innovations from livestock research is primarily the commercial poultry industry. Most of the research in the livestock industry is on poultry feed, although there is some research on swine and aquaculture feed. Also, there is one large poultry breeding and disease research program in India and a swine breeding operation in Thailand where pork production is important. The most livestock research is in India followed by Thailand and then Indonesia or the Philippines. India, has the largest commercial poultry industry. Pakistan has a large industry also, but very little research which is somewhat surprising. Some critics of the Pakistan feed industry have suggested that there has been collusion between large

producers to keep prices high and prevent compeition on the basis of feed quality. However, this study was not able to confirm or deny this accusation. Thai research is unusually large because of the large commitment of one local company to livestock research. This company uses the research in Thailand as the headquarters for regional research for its operations in Southeast Asia and Taiwan.

The private plantation industry in Malaysia is the largest in Asia. The Indonesian industry is also large, but much of that industry is owned and operated by government corporations. The Philippines also has some large plantations of more recent origin in bananas and pineapples. Thailand has rubber, oilpalm and pineapple plantatins. Expenditure on research in Malaysia seems to have followed the fortunes of the industry. As yet, the purchase of some foreign-owned plantations by government owned banks does not seem to have affected the management or research of these plantations. Plantation research in Indonesia has been determined almost entirely by government decisions. Private research stopped in Dutch plantations when they were nationalized in 1958 and in the other plantations when they were nationalized in 1965. Some of the major companies were denationalized in the late 1960's and four companies re-established their research program at that time. Plantation research in the Philippines started in the late 1960's with the establishment of the banana and pineapple export industries. It grew rapidly as the industry grew but declined since 1980 as the economy declined.

Research expenditure in plantations and processing in India is dominated by Hindustan Lever which originally started to do research on vegetable oils to replace imports of their main inputs. Their research looked

at nontraditional sources of oil and from time to time at improving various oilseeds. Much of their research is still on oilseeds. Recently, they have branched out into completely new areas like shrimp culture and agricultural inputs like plant growth regulators, biological nitrogen fixation, and natural pesticides. This means that some of their research should probably be reclassified into other categories.

Cigarette industry research in South Asia started in British India and then has been introduced into Pakistan and Bangladesh by the demand for Virginia tobacco. This demand has been created by the growing demand for cigarettes and government restrictions on imports of tobacco which forced local production. To develop the appropriate technology, applied research was required in each country. The decision of companies in Thailand and the Philippines to do research is also tied closely to government policies because tobacco in both countries is heavily taxed and regulated by the government.

3.3 Summary of Government Policies and their Impact on R&D

The policies determining research expenditure described in previous sections can be divided into four general types: industrial policy; trade policy, government research and educational policies; and science and technology policy. Industrial policy includes government decisions on what industries should be in the public sector, restrictions on firm size, taxes, price controls and subsidies, foreign ownership and a number of other things. Trade policies could also be part of an overall industrial policy. Trade policies

include tariffs and quotas which protect infant industries of certain types or exchange rate policies and the rationing of foreign exchanges. They influence the amount and direction of private research through their effect on the profitability of certain activities like research and technology transfer.

Government research and education policies include how much government research there is and what topics are covered. Government research can lower the cost of private research or technology transfer by conducting basic research which reduces the time it takes private scientists to make a discovery and by providing technical information which helps firms select the right technology to transfer. An educational policy that invests government money in higher education makes research and technology transfer cheaper by reducing the costs of researchers and technicians.

Science and technology policy includes laws and regulations that cover the private sector's activities in research, development and technology transfer. Thus, they include tax incentives for R&D, patents and other types of intellectual property rights, and restrictions on royalties and technical agreements.

Some of the policies affecting private research in the six main countries surveyed are listed in Table 4. This is not a comprehensive list, but it does capture the flavor of current policies in these countries. It indicates that in countries like Bangladesh which tends to be the least modernized, the governments are heavily involved in supplying inputs, public research has little or no formal contact with private research and there are few policies to induce private companies to do research.

Table 4. Policies Affecting Private Research.

	India	Thailand	Philippines	Indonesia	Pakistan	Bangladesh
I. Industrial Policy						
Government supply	Inputs and processing seeds, fertilizer, pesticides, tractors	Some seed & fertilizer	Little	Seeds, fertilizer, pesticides	Seeds, fertilizer	Seeds, irrigation pumps, pesticides & tea estates
Restrictions on firm size & market power	Yes	Not much	Marcos encouraged large firms	Yes	Some	Some regulated monopolies
Regulations	Many	Few	Effective on pesticides	Many	Many	Many License required
Foreign ownership	(40%) Maximum License required	Few restrictions but tax incentives for joint ventures	Some restrictions License required	Restricted License required	Restricted License required	Restrictions - 50% for expansion of pesticide companies
II. Import Policy	High tariff & quantitative barriers	6% tariff & special quantitative restrictions as special incentive	Moderate tariffs	Many barriers	Quantitative Barriers Tariffs	No tariffs on seed imports & active ingredients of pesticides. Quantitative restrictions on irrigation pumps
III. Government Education Research						
Investments in HC	Yes	Yes	Yes	Yes	Yes	Yes
Agribusiness influence on priorities	Little	Some	Some	None	Little	None
Contract research?	Some	Some	Only consultants from universities	No	No	No
Joint research?	?	?	Some - Twin Rivers & ANSA farms	No	On cigarette tobacco	No
IV. S&T Policy						
Tax incentives	Write off 125% R&D costs	No incentives of R&D & but tax incentives for new technology	No	None	No	No
R&D inputs	Import some machinery duty free Restrictions on germplasm imports	Free entry	Duty free imports Encourage foreign scientists as consultants	Restricted	?	No policy
Patents	Only process patents on chemicals No product patents on agricultural inputs	New system - weak	Strong system with utility patents	No patents	Strong laws enforcement?	Strong laws enforcement?
Restrictions on Royalties and Technical Agreements	Yes	No	Yes	?	Yes	?

Thailand is the most laissez faire in its policies both towards the private sector in general and towards research in particular. The Thai government supplies seed only for some of the self-pollinated crops like rice. Most of the fertilizer and pesticides are supplied by private firms. There are few policy incentives for local research and so all that is done is done because there are good economic reasons.

In contrast, in India the central or state governments produce and supply a large share of fertilizer, both hybrid and self-pollinated varieties of seed and a more limited share of pesticides and tractors. The role of multinationals is severely restricted and imports of inputs are also limited. There are some policies to encourage local private R&D like tax incentives for R&D. The investments in public research and education can encourasge private R&D depending on what type of public research is carried out. Other policies reduce agricultural R&D like the absence of product patents on agricultural inputs and government licensing requirements for large firms which restrict their ability to commercialize the products they develop.

One factor which is hidden by the aggregate data but clear from the individual firm data is the importance of firm size in determining research. Most of the R&D in each country is conducted by the largest firm in the country. This is clear in plantations, farm machinery and livestock processing. The author's obserservations are supported by empirical studies in the Philippines and

In countries like Bangladesh, government policies are not the main constraint to private sector research and technology transfer. The main constraint is that they do not have modern agriculture. These countries do, however, frequently have laws that restrict any private research that might

occur. The major need is for public sector activities to develop infrastructure that will lead to modern agriculture. These activities include investments in physical infrastructure, human capital, agricultural research and extension and policies to encourage private investment in modern input and processing industries.

In Indonesia, India and perhaps Pakistan, policies appear to be a major constraint to the development of a private input industry and also to private sector research and technology transfer. Therefore, policy reform should be a major priority along with continued investment in the public infrastructure required for agricultural modernization.

Thailand, the Philippines and Malaysia have higher investments in private agricultural research relative to the size of their agricultural sectors. This is due to the modernization of their agricultural sectors and relatively less government regulation and government ownership of private input supply, plantation or processing industries. Their private research intensity is still low relative to the standard set by Brazil or developed market economies. There are three possible reasons for the low level of private research. First, the agriculture in these countries is still not modern, which limits the size of markets for new technology. Second, there are still plenty of government regulations in these countries and, in Malaysia, the major plantations are being purchased by government owned banks. Third, the private sector almost always invests less than the socially optimal amount in research and so government programs are required to bring the level of private research up to the desired levels. Both Brazil and the United States have policies to encourage private research. These include government research programs that do basic research which private industry needs but

can not capture the gains from and patent policies that encourage local research.

The policy implications for Thailand, the Philippines and Malaysia would seem to be (1) continue to modernize agriculture, (2) examine current policies to see if they are restricting private research and technology transfer, and (3) provide special incentives for private research.

4 Impact of Private Research and Technology Transfer

There are several regions where private sector research and technology transfer activities have had an impact on agriculture production. This survey did not attempt to measure these impacts. Instead we attempted to identify places where there are possibilities for quantifying the impact of private sector research and measuring the effect of government policies on research and technology transfer. The third phase of this project is intended to measure impacts.

The most important impact of private sector research in Asia is on the plantation industry. The oilpalm varieties that have made Southeast Asia the world's fastest growing producer of edible oils are largely the result of private research. Many of the clones used in rubber production in Indonesia and Malaysia were developed in Harrison and Crossfield's breeding program in Malaysia. Yields of oilpalm were increased and costs of production reduced by the introduction of the oilpalm pollinating weevil. Through the joint efforts of Unilever and the Commonwealth Institute of Biological

Plantation Control, research has substantially reduced the cost of pest control and fertilizer use. Private research has had an impact on oilpalm and rubber yields in Africa and Latin America also. Banana research has had an important impact on the costs of production and meeting Japanese and U.S. import standards for Philippine bananas and pineapples. The impact of private banana research has been even greater in Latin America.

The next most important impact of research has probably been on the seed industry. This generalization probably holds true for Asia and certainly holds true if Latin America is added. The private sector developed new high yielding corn hybrids which are commercially planted on several hundred thousand ha. in Thailand and the Philippines. The same corn hybrids are currently spreading to Indonesia and Malaysia. In India, pearl millet hybrids, corn hybrids and sorghum hybrids developed by the private sector have spread to over two million ha. Private research has had an even more important impact in Argentina with three million ha. of private hybrid corn and Brazil which has over seven million ha. of private hybrid corn. Private seed research also appears to have been important in Zimbabwe which has a million ha. of hybrid corn and possibly Kenya which has 850,000 ha. of hybrid corn (CIMMYT, 1986)..

Pesticide research in Asia has had limited impact. Research by agricultural chemical companies in Asia have identified chemicals to control *Rottboellia exalta*, the most serious weed problem in corn in the Philippines. Fungicides for seed treatments of corn for downy mildew were developed in Indonesia and are widely used in Southeast Asia. New rice herbicides were developed in Thailand. Research in Southeast Asia has developed safer and cheaper methods for applying pesticides. Private research has allowed

pesticides developed elsewhere to be registered so that they can be used in Asia.

Private companies have probably had more impact on agriculture by transferring technology than by developing new technology through R&D. Fertilizer and fertilizer production technology were imported from North America, Europe and Japan. The first generation of tractors and all pesticides were developed elsewhere and transferred to Asia. The poultry revolution in Asia was initiated by Arbor Acres and Shaver in the early 1960's. American and European companies continue to be the source of most commercial poultry breeds. The technology for commercial swine production has been transferred from the United States, Europe and Taiwan to Thailand, the Philippines and Singapore by the private sector. Private companies have rapidly transferred rubber and oilpalm technology between Malaysia, Indonesia, Thailand and the Philippines. Banana production for export and pineapple production for canning were both based on introduced technology.

The private sector has also played an important role in the diffusion of technology within Asian countries. In Thailand, Charoen Pokphand and Cargill are selling the corn varieties developed at Kasetsart University. In the early days of the Green Revolution, Esso helped spread HYV wheat and rice and fertilizer in Pakistan and the Philippines.

Charoen Pokphand has conducted three week practical courses on poultry production for farmers since 1978. It has expanded this course to a second location in Java. Over 1,000 farmers have taken this course. Large integrated poultry operations in Thailand and the Philippines provide technical assistance to their contract farmers. Buyers and technicians in export

industries and processing industries like Bangladesh Tobacco Company provide extension advice to farmers on varieties and management practices that will provide high quality cigarette tobacco at a low price. Maharashtra Hybrid Company provides technical assistance to about 6,000 Indian farmers who produce seed on contract.

Two other ways in which the private sector spreads technology are through consulting firms and spinoff companies. The most important agricultural consulting firms are in Malaysia where they are divisions of the major private plantation companies. They provide advice on planting and management of plantations in Malaysia, Indonesia, Thailand and elsewhere. The main place that we observed spinoff companies from the public universities was in Thailand. There a number of small seed companies were founded by ex-faculty members and students from Kasetsart University using inbred lines from Kasetsart University.

Although the impact of private research and technology transfer has generally been positive, it is important to note that it can also have negative affects. When a new production technology is widely adopted, almost always someone loses. In general, early adopters and consumers benefit from new technology, while late adopters and nonadopters lose. Increased production of corn, sorghum and pearl millet took place mainly in the most favored agricultural regions where these crops are grown. Increased supply depressed prices for farmers in the poorer areas. Commercial poultry production has affected the backyard poultry producers. Herbicides and farm machinery for cultivation and threshing have displaced labor in some places. Pesticides have saved lives by eliminating diseases like malaria but have caused death and sickness when used improperly. Research also affects

the international distribution of income. The gains in oilpalm productivity in Malaysia and Indonesia have led to lower prices for Philippine coconut producers and United States soybean producers.

Private research may also affect overall priorities of a country's research system. In the Philippines, 20 percent of corn production is yellow corn which is used as animal feed, while 80 percent is white corn for human consumption. Almost all private research is on yellow hybrids. Much of the government's research is also on yellow corn, although they are working on varieties rather than hybrids. The private sector is spending thirty million pesos on corn research and has four PhD corn breeders while the government has one PhD corn breeder and is spending six million pesos on corn research. This leaves almost no one doing research on white corn which is an important food crop. A similar situation is found in the plant protection area in Pakistan and the Philippines where many government scientists were hired by pesticide producers and distributors. Other government scientists are consultants for these companies, and many others spend their time testing new chemicals in the registration process. Few scientists are left to develop integrated pest management systems or to work on biological control.

There is sufficient quantifiable impact of the private sector that a third phase of this project appears to be justified. We propose to look at the seed industry and the pesticide industry in more depth. The seed industry study, which will have the most emphasis, should allow us to assess the impact of policies on private research and technology diffusion activities since local research is a necessary part of an effective seed industry. The chemical industry will allow us to focus more on policies which influence

the transfer of technology since this technology requires less local research. When the impact of policies on private research and technology transfer has been assessed, we will attempt to quantify the impact of private research and technology transfer on agricultural production and prices. In this way, we can quantify the costs and benefits of the policies to society.

5 Preliminary Policy Suggestions for LDC Governments and AID

It is difficult to provide more than preliminary suggestions at this point because of three factors: first, the lack of empirical studies on the impact of most of the possible policies; second, each government and society has different and frequently internally inconsistent goals; third, the optimal policies depend on level of development of private sector.

5.1 LDC Policies

We will make our job easier by assuming that the goal of these countries is to increase agricultural productivity through more private sector activity. The following policy suggestions for developing countries appear to be justified on the basis of the preliminary evidence that we have gathered.

1. The policy emphasis of governments must change with levels of development. During the early stages of development, governments like Bangladesh must concentrate on the development of the physical and institutional infrastructure for modernization. As development progresses political effort must shift to more emphasis on developing the policy climate

conducive to private research by eliminating government constraints to research and technology transfer. Governments in this stage must still invest in infrastructure for development. Finally, when countries have reached a stage in development where infrastructure and policies are no longer major constraints to private research, the government will have to shift its emphasis to developing policies that will encourage the private sector to invest more in research.

2. Countries should eliminate laws or regulations that prohibit private research. Goverments' decisions that they do not want new chemicals or the products of the new biotechnology tested in their country are clearly justifiable. There appears to be little justification, however, for prohibiting private research just to protect a government monopoly on R&D. In the past, such regulations have restricted the amount of seed research in the Philippines and Pakistan.

3. Companies must be allowed to commercialize the products they develop through research or technology transfer. In several countries, the way seed laws are administered appears to have to prevented companies from commercializing certain new varieties or hybrids. Some Indian companies have been prevented from commercializing chemical products that they developed in their laboratories. Such laws or regulations eliminate any incentive to do research.

4. Continued investment in public sector research is required, but public research must change with development. Initially, it does high payoff projects to establish itself. As modernization takes place, some high payoff projects are taken over by the private sector. Then the public sector must do research on a portfolio of projects that includes some high payoff

projects, more work on poor people's problems and more basic research which supports private sector research.

Examples of some of more basic public research programs are the research on and release of new inbreds to the private sector of cross pollinated crops. In Southeast Asia, the identification of resistance to downy mildew was the key to the hybrid corn industry and private seed research. In India, the research of the government and ICRISAT that improved pearl millet was a key factor in the development of the best hybrids on the market in India. In the near future, the hybrid rice research of China, IRRI, Indonesia and other governments may lead to rice research and seed industries similar to those in corn and pearl millet.

At present, several government research programs need more financial support. The Bangladesh and Pakistan systems are developing rapidly but continue to need more local support. The Philipppines and Malaysia have government systems that have been declining in recent years. The Philippines system requires more resources after several years' reduced expenditure in both nominal and real terms. The reputation of Malaysian research institutes is clearly declining in the eyes of the plantation industry in Malaysia, Indonesia and the world. The reasons for this decline seem to be internal politics rather than money.

5. In countries where there is a fairly well developed private sector, special incentives for private research may be effective in inducing companies to invest in more research. Such measures could include subsidies - particularly on credit - and tax incentives for research. Governments might underwrite venture capital funds. Governments might also promote more effective property rights like better patent protection and new types

of patents such as the utility patents that have been used effectively in the Philippines (see Pray, 1986b). They might reduce constraints on firm size - studies in India and the Philippines as well as developed countries suggest that larger firms invest a higher percentage of their sales in research than small firms (Mikkelsen, 1984 and Sinha, 1983). At the same time, most governments do not want to be promoting monopolies.

6. The most important input for R&D and technology transfer is scientific and technical manpower. Therefore, governments need to increase their investments in higher education and the training of scientists in the world's leading centers of research in various agricultural fields. At present, support for such training among donors is declining and so local governments must take up the slack. Overseas training not only provides benefits in terms of education, but also is important in developing networks with scientists throughout the world. These connections are valuable if scientists are in the private or public sector. In Pakistan and the Philippines, I met private sector scientists who continue to visit their U.S. professors periodically to exchange germplasm and catch up on the latest in biotechnology research.

7. Technical support by government research and development institutions can encourage more innovation - particularly by local industries. In the 1960's, advice by scientists from the Indian Council of Agricultural Research and the Rockefeller Foundation was important in establishing the research programs of several Indian seed companies. Programs by the Thai and Philippine governments in cooperation with IRRI have spurred innovative activity by small firms by providing them with prototypes and improving the skills of the firms' technical people.

8. A number of government programs have served to encourage the development of some of the input and processing ilndustries which do transfer technology and conduct research. Some successful examples include government technical support for the seed industries in Thailand and India.

Section 3.3 listed a large number of government policies that affect research. There is no strong justification for changes of many of those without further research. Key issues include (1) the impact of preventing multinationals from conducting research and selling modern technology; (2) the impact of patents and plant breeders' rights at early stages of development; (3) the impact of various policies that limit the size of companies and the amount of competition; and (4) the impact of import restrictions to protect selected key industries.

In the biotechnology area, many policies are being tried by governments. Most governments have set up public sector biotechnology research programs of some type. Joint ventures and venture capital are being encouraged with tax breaks and incentives. It is clear that some governments are going to get stung by outside firms if the government does not have the technical manpower to assess the products that they are supporting with taxpayers dollars. One foreign "biotechnology" has had its main success in India, where it is in a joint venture with a state government corporation, and in Indonesia, where it sells its product to government plantations. In Pakistan and other countries in which private farmers evaluated this product on the basis of its profitability, this company has not done very well. This suggests that governments should support science rather than trying to pick the winners in biotechnology.

5.2 Current AID Activities

AID has invested in infrastructure. It has invested in the government research systems of all of these countries and these investments have had high rates of return (Pray and Ruttan, 1985). AID has invested in the International Centers, and these investments have had large payoffs (Anderson, 1985). AID has invested in agricultural universities which trained the scientists and technicians of the private sector. AID has invested in physical infrastructure like roads and irrigation systems.

AID has assisted in the development of modern input industries in a number of ways. Before and during the Green Revolution, AID encouraged development of the demand for modern inputs by providing chemical fertilizer and pesticides as grants or soft loans. In some countries, AID has also provided irrigation equipment and tractors. These were in turn sold at subsidized prices to farmers which probably led some farmers to adopt modern inputs more rapidly. The negative side of such programs is that they crowd out private input supply companies if they continue too long.

AID has also had programs to encourage local production of modern inputs. In India during the the 1960's, AID staff provided technical assistance to the fertilizer industry, pesticide industry and seed industry. AID advisors provided assistance in organizing the industry associations of pesticide and fertilizer producers. At present, AID projects are providing training and technical assistance to the Thai seed industry and the Bangladesh fertilizer industry. AID provided assistance in the framing of seed laws in India and Thailand and the first pesticide regulations in India in the 1960's.

AID has had some success encouraging policies changes in Pakistan and

Bangladesh where it worked with the World Bank to privatize fertilizer, pesticide and irrigation equipment distribution.

Recently, AID missions have developed a number of projects which are specifically aimed at assisting private sector research and technology transfer. In Thailand, AID is financing a project which will directly support private sector research though: (1) matching grants for research that private companies want done; (2) subsidized credit for joint ventures that transfer technology, and (3) an information center for science and technology. A number of AID missions hope to promote technical change through joint ventures between U.S. and Asian companies. The specific programs vary considerably. In Indonesia, a consulting firm is paid to facilitate contact between firms. In India, the project provides credit as well as publicizing joint venture opportunities to the U.S. firms.

Table 5 is an incomplete catalogue of some of the things that AID missions or centrally funded projects like the CGIAR institutions are doing to assist the development of private sector research. AID projects and policy dialogue do take a pattern based on the level of development of the private sector in the country. For example, in Bangladesh one does not worry much about science and technology policy until there is a private input industry and a public research and educational system that can train and provide experience to private scientists. In contrast, in Thailand, where there is a well developed private sector, AID is concentrating its efforts on policies to encourage more private research directly.

Table 5. Current AID Activities Effecting Private Secstor R&D in Asia.

	India	Thailand	Philippines	Indonesia	Pakistan	Bangladesh
Industrial Policies	Nothing	Seed Industry Project	Restructuring Coconut & Sugar Industries IRRI Influence on Pesticide Policy	IRRI Mechanization Projects AID/IRRI/AARD Influence on Rice Pesticide Policy	Privatization of Pesticide Fertilizer, Agricultural Machinery and Seed Liberalizing Agricultural Processing Industries	Privatization of Pesticide Fert., Ag. Mach. & Seed
Public R&D	ICAR Project	CIMMYT/KU Corn Research CIMMYT Barley S&T Project-Biotech Research at Government Universities IRRI Rice Research	Development of PCARRD & Regional Research IRRI Plant Breeding & Pest Control	AARD & University Development Projects	PARC and NARC Development NWFP Ag. U.	Support for BARC, BARI, BRRI
S&T Policy	Promoting U.S.-Indian High Tech Joint Ventures	S&T Project 1. S&T Policy Studies 2. Matching Funds For Private Research 3. Technology Information Center	IRRI/Ministry of Agriculture Rice Mechanization CIMMYT Germplasm to San Miguel Corporation	Subsidize Consulting Firm to Bring Together Joint Ventures	Nothing	Nothing

This table also contains some of the activities of the International Agricultural Research Centers (IARC's) of the Consultative Group for International Agricultural Research (CGIAR). AID provides a quarter of their core budget as well as supporting many special projects that are executed by the CG centers. The CG centers are primarily commodity institutes, but the International Board for Plant Genetic Resources is specifically working to improve germplasm collections which primarily affects the seed industry. In addition to the CG centers, there are several other centers that deal directly with agricultural input industries: the International Fertilizer Development Center (IFDC), the International Irrigation Management Institute and the International Center for Insect Physiology and Ecology in Kenya.

Since the purpose of the CG is to help alleviate world food problems, it deals with the poorest countries and crops that the poor grow and eat. These are generally the countries and crops in which the private sector has the least interest. Therefore, the CG deals primarily with government institutions and the CG's institution-building activities have focused on government institutions.

The international centers have also, however, had an important impact on private sector research and technology transfer. First, they have helped increase the size and efficiency of the government agricultural research systems of LDCs. This impact has been documented in the recent impact study conducted by the CGIAR (Anderson, 1985). Joint research by the CG centers and local government institutions led to private hybrid corn research in Thailand and the Philippines, encouraged private pearl millet research in India and is the basis for private hybrid rice research in the Philippines, Pakistan and India. In addition, germplasm from CIMMYT

and ICRISAT is used in the research programs of multinationals and local companies throughout Asia. These lines are more important to local companies than to multinationals because the multinationals already have their own germplasm collections. Interaction with scientists and the provision of prototypes of power tillers and threshers from IRRI have stimulated informal research in the Philippines and Indonesia.

A second impact of the International Centers has been through training and technical assistance. CIAT has trained a number of private sector people in their seed production program and has established a network of professionals in the seed business in Latin America. IFDC has provided training for the fertilizer industry and dealers in a number of countries. It has also provided technical assistance to the fertilizer industry . The demand for agricultural mechanization of the outer islands of Indonesia has been encouraged by the IRRI rice mechanization program which has promoted mechanization by demonstrating prototypes.

Third, the centers they have influenced government decisions and policies. For example, IRRI's research on pest management led to a government integrated pest management program for control of brown plant hopper in Indonesia and to the removal of specific pesticides from the subsidized list in the Philippines because these pesticides caused resurgence of some pests and were very dangerous. The results of IRRI's pesticide testing program guides governments' decisions about approving a new pesticide and in some cases buying the pesticide.

5.3 AID Policies For the Future

In general, AID should assist the programs and policies identified in the section on LDC policy that will induce more private sector research and technology transfer.

AID missions must assess the extent to which there is a private sector industry in existence which might make profits from private research. If such industries are not in existence, then the mission should place its emphasis on helping to develop those industries. If the country need basic infrastructure, AID must help develop it - there are no short cuts to the development of basic infrastructure. If policy changes are needed, then AID may be able through well researched studies to persuade the local government that changes are needed. In a few cases, AID may have sufficient political clout to force changes (or include them in a World Bank/IMF structural adjustment package). If there is a private sector which could make profits from R&D or technology transfer, then AID should be looking at the specific policies to induce more research.

Policy dialogue on science and technology policy may be most effectively pursued in places where this policy is the subject of public debate like India and Thailand. AID could finance papers and conferences on private sector research and policy constraints. These conferences should include opportunities to meet with officials from other countries and discuss common problems. Such conferences could bring some light instead of just rhetoric on some hot topics like biotechnology.

AID projects that support public sector research are needed in all stages of development represented by the Asian countries in this study. It is the

type of research that changes. In the earliest stages, AID's assistance to research must concentrate on increasing the productivity of the major foodgrains. As the country develops private input and processing sectors, the emphasis should be changed to research that serves to encourage private research to develop and also to important activities that are not profitable for the private sector like working on poor peoples' crops. Unfortunately, many private companies surveyed felt the public research sector was working against them. This complaint came up in India, Pakistan and Thailand. AID should use its influence encouraging linkages and cooperation with between the public and private sector.

AID should also encourage public research programs to test new products and provide what the public perceives to be unbiased scientific information. This is valuable for business because it allows effective technology to spread more rapidly and forces competition between firms to be based on technology not simply on the marketing skills of the companies. This will be especially important for the general public when the new genetically engineered products arrive and as problems arise with pesticides. It is also important to farmers who may have difficulty sorting out the claims of various pesticide or seed companies.

AID must continue to support the CGIAR and some of the other international agricultural research organizations. The IARCs have been a major force in creating opportunities for private sector development. Special funding for projects like the IRRI/mechanization project have been very effective in the past and can encourage private innovation in the future.

There are a number of possible policies and programs for encouraging private research and technology transfer to countries which have a large

private sector. Unfortunately, few of these policies have been around long enough to have any track record. AID should be supporting some experiments in this area of S&T policy. Some of the possible projects include education and technical assistance on regulation and testing (Barton, 1986). Financing joint public-private research projects or subsidizing private research is a real possibility in the Philippines, Thailand and India. Pakistan and Indonesia also have a few opportunities. A competitive research grants program that both private and public sector could compete for might encourage productive competition between the public and private sector. AID could subsidize international information flows - to help companies get best technology or best advice and help governments guide companies to the best technology. A venture capital fund for biotechnology companies has also been suggested. Subsidies for the D part of R&D or the adaptation part of technology transfer might also be considered.

AID needs to support more research and informationexchange about which science and technology policies work and which do not. There is not enough information to draw sound conclusions about the efficacy of many policies that have been suggested and are being tried. This suggests that more money needs to be invested in academic studies which attempt to measure quantitative impacts of these policies in a rigorous way. It also implies that the many experiments being conducted by governments and AID missions should be monitored fairly carefully by AID and the results communicated to other AID missions and their host governments. The Thai S&T projescts may be applicable in the Philippines and elsewhere. This might be an appropriate time for an AID conference on what AID is doing now in the areas of (1) policy dialogue on S&T issues, (2) promoting

joint ventures, and (3) public-private research linkages.

References

Agricultural Research Institute (ARI). "A Survey of U.S. Agricultural Research by Private Industry III," Bethesda, Maryland: ARI, July 1985.

Anderson, Jock, "International Agricultural Research Centers: Achievements and Potential," Washington, CGIAR, The World Bank, 1985.

Barton, John, "The Role of Private Enterprise in Technology Transfer," prepared for USAID, August 1986.

CIMMYT Unpublished Survey on Corn Varieties, 1986.

Jabba, M. A., "Commercialisation of Agricultural Equipment Generated by R&D System in Bangladesh," Working Paper, International Labour Office, Geneva, 1985.

Mikkelsen, Kent A., "Inventive Activity in Philippine Industry," PhD Thesis, Economics Department, Yale University, 1984.

Paitoon Wiboonchutikula, "Total Factor Productivity Growth of the Manufacturing Industries in Thailand, 1963-1976," PhD Thesis in Economics, University of Minnesota, 1982.

Pray, Carl, "Private Sector Research and Technology Transfer in Asian Agriculture: Report on Phase I, AID Grant OTR-0091-G-SS-4195-00," Economic Development Center Bulletin Number 85-5, University of Minnesota, 1985.

Pray, Carl, "Agricultural Research and Technology Transfer by the Private Sector in India," Economic Development Center, Report Number 1, University of Minnesota, October 1986a.

Pray, Carl, "Agricultural Research and Technology Transfer by the Private Sector in the Philippines," Economic Development Center, Report Number 2, University of Minnesota, October 1986b.

Pray, Carl, "Agricultural Research and Technology Transfer by the Private Sector in Indonesia," Economic Development Center, Report Number 3, University of Minnesota, October 1986c.

Pray, Carl, "Agricultural Research and Technology Transfer by the Private Sector in Thailand," mimeo, Rutgers University, 1987.

Pray, Carl and Vernon W. Ruttan, "Completion Report of the Asian Agricultural Research Project (Contract No. AID/ASIA-C-1456), Economic Development Center, Bulletin No. 85-2, University of Minnesota, St. Paul, 1985.

Sinha, Arun P., "Innovation in Indian Firms: Myth and Reality," *Economic and Political Weekly*, September 3 and 10, 1983.

World Resources Institute, *World Resources 1986*, New York: Basic Books, Inc., 1986.

Publications Based On This Project

Echeverria, Ruben, "Transfer of Technology by U.S. Seed Industry," M.A. Thesis, Department of Agricultural and Applied Economics, University of Minnesota, 1985.

Pray, Carl, "Private Sector Research and Technology Transfer in Asian Agriculture: Report on Phase I, AID Grant OTR-0091-G-SS-4195-00," Economic Development Center Bulletin Number 85-5, University of Minnesota, 1985.

Pray, Carl, "Agricultural Research and Technology Transfer by the Private Sector in India," Economic Development Center, Report Number 1, University of Minnesota, October 1986a.

Pray, Carl, "Agricultural Research and Technology Transfer by the Private Sector in the Philippines," Economic Development Center, Report Number 2, University of Minnesota, October 1986b.

Pray, Carl, "Agricultural Research and Technology Transfer by the Private Sector in Indonesia," Economic Development Center, Report Number 3, University of Minnesota, October 1986c.

Pray, Carl, "Agricultural Research and Technology Transfer by the Private Sector in Thailand," Rutgers University, 1987.

Pray, Carl, "Agricultural Research and Technology Transfer by the Private Sector in Pakistan," Dept. of Agricultural Economics and Marketing, Rutgers University, 1987.

Pray, Carl, "Agricultural Research and Technology Transfer by the Private Sector in Bangladesh," Rutgers, 1987.

Pray, Carl "Private Sector Agricultural Research in Asia," forthcoming in *Policy for Agricultural Research*, Vernon W. Ruttan and Carl E. Pray (eds.), Boulder, Colorado: Westview Press, 1987.

Pray , Carl and Ruben Echeverria, "Impact of U.S. Technology Transfer: A Case Study of Hybrid Corn," forthcoming in Sundquist, 1987, untitled.

Publications From Related Projects

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.

Pray, Carl E., "Research and Productivity in Grain Production in Asia: The Colonial Heritage," Paper presented at the International Association of Agricultural Economists Meetings, Jakarta, Indonesia, 1982.

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.

Bulletin Number 81-2, Vernon W. Ruttan, "The Asian Bureau Agricultural Research Review," March 1981.

Bulletin Number 81-3, Robert E. Evenson, Paul E. Waggoner, Paul R. Bloom, "The Agricultural Research System of the Philippines: A Reconnaissance Report," May 1981.

Bulletin Number 82-1, Carl E. Pray, Vernon B. Cardwell, Bo G. Crabo, Paul S. Teng, "The Agricultural Research System of Pakistan: The Report of the Minnesota Reconnaissance Team," Revised October 1982.

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.

Bulletin Number 83-2, Vernon W. Ruttan, "Reforming the Global Agricultural Research Support System," March 1983.

Bulletin Number 83-3, Joseph G. Nagy, "Estimating the Yield Advantage of High Yielding Wheat Varieties" The Use of On-Farm Yield Constraints Data," September 1983.

D. Reprints

UMEDC (reprints) 82-1, Carl E. Pray, "The Bangladesh Journal of Agricultural Economics," Vol. II, December 1979, Number 2.

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

UMEDC (reprints) 82-3, V. W. Ruttan, "Bureaucratic Productivity: The Case of Agricultural Research," E.C. Pasour and M.A. Johnson, "The Case of Agricultural Research Revisited," V. W. Ruttan, "A Rejoinder."

Jospeh 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.

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

Joseph G. Nagy, "The Overall Rate of Return to Agricultural Research and Extension Investments in Pakistan," Pakistan Journal of Applied Economics (1985):17-28.

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

Vernon W. Ruttan, "Toward a Global Agricultural Research System: A Personal View," Research Policy 15(1986):307-327.