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# PRIVATE SECTOR RESEARCH AND TECHNOLOGY TRANSFER IN ASIAN AGRICULTURE: REPORT ON PHASE I AID GRANT OTR-0091-G-SS-4195-00

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Private Sector Research and
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# Executive Summary

The first phase of this project had three major goals: (1) to review the literature on the determinants of R & D and technology transfer by the private sector; (2) to talk to firms in the U.S. about their decisions to do research in or transfer technology to Asia; (3) to identify the main activities of the donors in supporting private sector research and development and technology transfer.

This report is based on three types of sources. We interviewed scientists and marketing people from about twenty major seed, pesticide, and poultry companies. We interviewed a number of officials in AID and the World Bank. We also reviewed a wide variety of published sources on the economics of research and technology transfer.

Economic theory and available empirical evidence suggests the following generalizations about private R & D:

1. Growth of a firm's or industry's market leads to growth in R & D.
2. R & D activity as a percent of sales increases with firm size up to a point and then level off or decline.
3. A market structure intermediate between monopoly and perfect competition promotes the highest rates of inventive activity.
4. Increasing the productivity of or reducing the cost of research will increase the amount of research.
5. In aggregate, private firms will not do the socially optimal amount of research because of the public goods characteristics of the output of research.

6. The ability of private firms to capture the gains from research varies between different industries due to differences in technology and property rights. Research on some crops and inputs will be further from the optimal level than others.

The literature suggests the following generalizations about technology transfer:

1. There are three stages of technology transfer - material transfer in which the actual seed or pesticide is transferred, design transfer when the design of a seed production facility or chemical factory is transferred and capacity transfer in which the capacity to do R & D to create new technology is transferred.

2. Both supply and demand side factors determine how much and what type of material transfer takes place. The supply of new technology will be determined by factors in the home country as well as factors in the importing country. Demand is determined in the importing country by the market size, environmental sensitivity of the technology, and government policies.

3. The choice of design transfer rather than material transfer is determined primarily by tariff barriers, cost structure of the home industry, the costs of transfer, and the size of the market.

4. Capacity transfer will be induced by large markets, environmental and political barriers to material or design transfer, and the relatively high costs of material and design transfer vs. developing local R & D capacity.

Data on Asian imports of technology embodied in inputs like fertilizers, agricultural chemicals, and agricultural machinery indicates that imports grew rapidly between 1965 and 1980 and then levelled off. The growth in Asian private sector R&D, particularly in the input supply industry, has been much more recent. Most of it started in the 1970s and has grown very rapidly since then. Research by processing and plantation companies dates back to the colonial period. It is growing in only a few commodities in a few countries.

The seed, chemical and poultry industry case studies indicate that the economic forces listed above do affect firms decisions. The seed and chemical industries also indicate government policies and research have played an important role in determining the level of technology transfer and research conducted by companies.

The impact of technology transfer by the private sector - especially by the fertilizer industry - was important in the rapid growth of rice and wheat production during the green revolution period. Chemical plant protection technology has been transferred by a combination of public and private sector but it is not clear how much impact this has had on productivity growth. The rapid growth of the commercial poultry industry in Asia was due to the private transfer of technology. Private sector research has had little impact on farm productivity in South and Southeast Asia as yet.

AID has had a positive impact on the growth of private sector research and technology transfer through programs that supported government agricultural research and education. Research projects in Thailand that were indirectly supported by AID support of CIMMYT produced the downy mildew resistant varieties which are the basis of the Thai corn seed industry. The leaders of private research programs and the seed and pesticide salesmen were trained at U.S. universities on AID funded scholarships and at local agricultural universities built with AID money. Policy dialogue has had some success. For example in Bangladesh and Pakistan AID projects encouraged the privatization of input supply. Earlier projects which supported public sector input supply operations may have had a negative impact on private sector research and technology transfer.

In phase II of this project the major issues we will investigate are:

1. How much private research is going on and what is being done?

2. What government policies have been most important in determining the level and direction of private R & D and technology transfer?

3. What AID programs have tried influence the level, direction and impact of private technology transfer and R & D?

4. Where are the major impacts of technology transfer and local R & D?

# Private Sector Innovation and Technology Transfer in the Agricultural Sector in Developing Countries

## I. Introduction

The purpose of this project is to better understand the role of the private sector in developing and transferring new agricultural technology to developing countries with special emphasis on Asia. It will attempt to do three things: (1) assess the present and future importance of private sector research in developing and transferring new agricultural technology; (2) measure the impact of private sector research and technology transfer activities on agricultural productivity and income distribution in Asia; and (3) determine the effect of government policies on private sector research and technology transfer. By better understanding the role the private sector has played in the past and can play in the future, we hope to be able to suggest ways in which the governments of developing countries and the United States Agency for International Development can promote a more effective role for the private sector.

The first phase of this project has three major goals: (1) to review the literature on the determinants of innovative behavior and the transfer of technology; (2) to talk to firms in the U.S. about their decisions to do research in or transfer technology to Asia; (3) to identify the main activities of the donors in supporting private sector research and development in developing countries or assisting the transfer of agricultural technology by the private sector.

This paper reports the findings of the first phase of this project. It contains five sections. The first presents a review of economic theory and empirical studies on research and technology transfer by the private sector. The second presents our initial impressions of the trends and levels of private agricultural research and technology transfer in Asia based on earlier research, our discussions with companies, and available literature. The third section applies economic theory to help understand the research and technology transfer by Multinational Enterprises and Asian private firms in three industries - seeds, agricultural chemicals and poultry. The fourth section discusses the impact of technology transfer and private research on Asian agriculture. The fifth section examines the activities of AID and other donors. The executive summary contains hypotheses to be tested and policies to be studied in the next two phases of this project.

## II. Review of Theory and Evidence on Private Research and Technology Transfer

### Determinants of Level of Research

There are three types of firms that conduct agricultural research: farms, input supply firms and processing and distribution firms. Expenditure by these firms on all types of research and development[1] in the U.S. is shown in Table 1. The absence of a category for farms indicates that they do a negligible amount of research except when they are acting as input suppliers e.g. small seed companies. In this paper we will concentrate on research to increase agricultural production. We are excluding post-harvest research to keep the study to manageable size.

The major purpose of research by input supply firms is to develop new and improved inputs to sell to farmers. The firms' profits from investing in research and development will depend on (1) the cost of research and development, (2) the amount of farmers' cost reduction or increased profit due to the new input, (3) the size of the market for the inputs.

The major purpose of research on agricultural production by processing firms is to develop new technology that will reduce their cost of production by reducing the cost of the agricultural commodity to be processed or traded. The profits from R and D by these firms will depend on (1) the cost of research and development, (2) the expected size of increased profits due

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1 We are using the National Science Foundation definition of research and development. R and D "includes basic and applied research in the sciences (including medicine) and in engineering, and design and development of prototypes and processes. It does not include quality control, routine product testing, market research sales promotion, sales service, research in the social sciences or psychology, or other nontechnological activities or technical services." Mansfield, 1968, p. 43.

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Table 1. Estimate of Industry Expenditures (in $ millions) for Farming and Postharvest Efficiency.

| | 1978 | 1979 |
|---|---|---|
| Farm input Industries: | 751-846 | 814-909 |
| Plant Breeding | 55-150 | 60-155 |
| Pesticides | 290 | 339 |
| Plant Nutrients | 3 | 3 |
| Total Plants | 343-443 | 402-297 |
| Animal Breeding | 49 | 55 |
| Animal Health (mostly veterinary drugs) | 99 | 99 |
| Animal Feed and Feed Ingredients | 30 | 133 |
| Total Animals | 178 | 225 |
| Farm Equipment and Machinery | 225 | 225 |
| Processing and Distribution: | | |
| Farm Produce Transport Equipment | 40 | 45 |
| Food Processing Machinery | 85 | 100 |
| Food Processing | 350 | 400 |
| Tobacco Manufacturing | 40-50 | 40-50 |
| Natural Fiber Processing | 10 | 20 |
| Packaging Materials | 116 | 129 |
| Total Processing and Distribution | 641-651 | 734-744 |

Source: Ruttan (1982).

to the reduction in commodity costs, (3) the size of the market for the final product. Both types of firms may also do research to improve the efficiency of their own production processes. The main determinants of the profitability of research which improves their production processes is (1) cost of R&D, (2) the size of the cost reduction due to new technology (3) the size of the market and the market share of the firm, (4) the ability of the firm to collect royalties by selling the process.

Most of the economics literature on private research and development concentrates on the process improvements in industry (Mansfield, 1968 and Kamien and Schwartz, 1982). There is less discussion of research on product development by input supply companies (or consumer good industries) (Stoneman, 1983). There is no discussion of the type of research carried out by the processing and trading firms but the models of process innovation can be modified to fit this type of research.

The certainty with which a firm can predict the size of the market for an innovation will vary with the type of industry and type of innovation. If the innovation is a new process that the innovator will use to make the same input or processed good, there is some knowledge about the demand curve for the product and the speed at which the process will be used. In the case of innovations from agricultural research by processing firms something is known about demand because the processed good has not changed but there is less certainty about the adoption of the innovation by farmers unless they are under a contract with the processor. In the case of an input supply company which has a new input, uncertainty of adoption also means uncertainty about the demand of the input.

Sherer (1984) has collected and presented data which gives an indication of the amount of these various types of research. He used patent data and Federal Trade Commission data of 443 large corporations to allocate R&D expenditures by industrial origin (where they are done) and by their ultimate use (where they will have their major productivity-enhancing impact). Most of the data are on the industrial sector but there are some interesting facts about the characteristics of agricultural research by the U.S. private sector. The data have one major limitation for agriculture because many of the firms which do agricultural research are not among the 443 large corporations in his data set.

Table 2 presents an abbreviated version of Scherer's table. Column one shows the total amount of private research conducted by the industries listed at the left of the table. Column two indicates the amount of research which is used in agriculture and forestry. Column three shows the research which increases productivity in food and tobacco processing. Most private sector technology used in agriculture is developed outside the agricultural sector in the industrial sector. Farm machinery, agricultural chemicals, motor vehicles and equipment, and pharmaceuticals are the main industries that did R&D which led to technology used in agriculture. The food industry also does a small amount of research that is used by farmers.

The other interesting characteristics of research by input supply firms is shown by reading across the table. Over 75% of research by agricultural chemical industries ($142.8 of $186.7) and farm machinery industries ($165.4 of $199.3) was used to develop new products used in agriculture. Less than one quarter of their expenditure produced new processes to improve their productivity.

Table 2. Technology Flow Matrix (millions of $).

| | Origin R&D | Agr. & For. | Food & Tobacco | Pharm. | Ag. Chem | Farm Machinery | Motor Veh. Equip. |
|---|---|---|---|---|---|---|---|
| Agriculture & Forestry | 128.10 | d | - | - | - | - | - |
| Food and Tobacco Products | 444.90 | 7.90 | 278.20 | - | - | - | - |
| Pharmaceuticals | 557.30 | 32.00 | 0.20 | 71.00 | - | - | - |
| Agricultural Chemicals | 186.70 | 142.80 | d | d | 34.20 | d | - |
| Farm Machinery | 199.3 | 165.4 | - | - | - | - | 0.1 |
| Motor Vehicles & Equipment | 1518.00 | 78.00 | 26.50 | 1.70 | 0.60 | - | - |
| Others | | ? | 218.30 | 22.60 | 10.90 | 19.20 | 308.10 |
| Total R&D Dollars Used | | 561.80 | 523.20 | 95.30 | 45.70 | 19.20 | 308.10 |

d represents entries that had to be suppressed to comply with FTC requirements not to disclose data about groups with less than four companies.

- is less than $50,000.

Source: Scherer, 1984.

The literature on R&D is in government on the importance of certain elements the profitability of research investments. The first factor is the cost and efficiency of research and development. The cost is a function of the price and availability of research inputs like scientists and technicians, physical equipment and facilities, and the cost of obtaining information about research elsewhere. The efficiency of the research and development process will be determined by the state of knowledge in this research area, the productivity of the scientists and the management of the research institute as a whole.

The second and third factors are the size of firm and the market structure of the industry which is doing the research. Kamien and Schwartz (1982) have reviewed the empirical literature on the topic of firm size and market structure. They conclude: "R&D activity, measured by either input or output intensity, appears to increase with firm size up to a point and then level off or decline." Regarding market structure they say: "The standard hypothesis tested is that the R&D activity increases with monopoly power. Little support for this hypothesis has been found. Instead, a new hypothesis has emerged that a market structure inter-meditate between monopoly and perfect competition would promote the highest rates of inventive activity." (p. 103 and 104).

A fourth factor is the potential size and structure of the industry to which results of research are sold. Industries will invest more in research if the size of the potential market is growing, if their share of the market is increased and if the elasticity of demand for the final product of the adopting industry is high. They should also invest more in research if the industry to which they are selling is competitive rather than monopolistic because competitive industries will generally adopt innovations faster than monopolistic industries.

If the company is a multinational, there are other factors, in addition to the general factors listed above which influence all firms, that influence its decision to do research. The multinational may derive benefits from research which help its profits elsewhere - i.e. seed companies can test germplasm under certain types of pests and diseases not available in their home country or they may develop germplasm that can be used elsewhere. This would tend to increase R&D above what needed locally. On the other hand the local subsidiary may be able to rely on R&D done in the central research facilities of the multinational and will do less research than a local firm facing similar research needs. Mikkelsen's study found that foreign firms did less research than local firms.

One of the few attempts to test the importance of these economic factors in the developing country context is Mikkelsen's thesis on the Philippines (Mikkelsen 1984). He developed a model of the R&D behavior of Philippines firms on the basis of economic theory and a preliminary inspection of Philippino data. He hypothesizes the following relationships: (1) there is a minimum threshold size below which a firm will not perform R&D; (2) firms within an industry above this threshold, R&D will increase with firm sales and research intensity will rise as firm size increases; (3) the desired level of R&D will also be determined by demand elasticity, research productivity and discount rate; and (4) industries with a few large firms will do less research than industries with one large firm and many small ones, but less than a perfectly competitive industry.

He tested these hypotheses on 1965-66 and 1979-80 data on Philippines industry. He found evidence of a minimum threshold size of firms although in his case study of the farm machinery industry all firms seemed to be engaged in some innovative activities. His analysis of the early data set indicated that R&D expenditures increase with firm size but at a less than proportionate rate. The 1979-80 data set included fewer and larger firms than the 1965-66 set. He found that R&D intensity increased with firm size. The only evidence on research productivity was the impact of the availability of foreign knowledge which should raise the productivity of local applied research. The 1965-66 data set indicated that there is more R&D in firms where a growing stock of international knowledge is available. There is no evidence that foreign technology stimulated local R&D in 1979-80. The evidence indicated that firms do more research when competition is many small firms and imports rather than other large firms which might copy the innovator's technology.

## What Technology Will the Private Sector Produce?

Binswanger (1978) argues that firms will invent technology appropriate to factor prices in a country unless the firm is a monopolist. He argues that a firm's choice of research to conserve different inputs will be determined by the expected price of those inputs unless the inventor is a monopolist in which case the theory is indeterminate. Stobaugh and Wells' (1984) evidence on the choice of technology by industrial firms in LDCs supports Binswanger's claim that competitive industries are more efficient than monopolized ones. Even competitive firms, however, do not necessarily choose the most efficient combination of resources. They found that neither local nor multinational firms choose the efficient technology unless there is competition. Firms tend to have a much higher capital labor ratio than is justified even with the use of shadow prices unless there is competitive pressure from other firms to reduce costs. If firms are the inventors as well as adopters and they choose capital-intensive methods, it is likely they would also invent capital-intensive methods.

The implications of theory for the appropriateness of the technology available to a whole sector are less clear. If firms are inventing technologies that are inputs to other industries, will the available technology be skewed in a certain direction? The amount of private research on different inputs depends on the appropriability of that knowledge and whether the amount of discounted quasi-rent is sufficient to make the investment in research and development a profitable one. This depends in part on the size of the market for the inputs which in turn is determined by the region's resource availability and prices. It also depends on noneconomic factors like the structure of the innovating and adopting industry as well as the property rights to inventions which governments establish.

The private input companies will do research on commodities which have large markets, in which the research process itself is likely to be highly productive, and in which they have protection against imitators. Private processors or producers will also work on less important commodities, if the firms have monopsony power in the markets for these commodities. The implications for agricultural research are that firms will work on: (1) major crops, (2) minor crops which are processed or exported, and (3) inputs which can be patented or have natural protection against imitation. Agricultural chemicals and machinery are examples of inputs which have some patent protection. Hybrid seed and poultry are good examples of products with natural protection.

## Implications for Output Growth and Income Distribution

Our basic assumption throughout this study is that technical change leads to economic growth and that economic growth is good. New products which are developed by research will be purchased only if people think they are useful and new processes of production will be adopted only if they reduce the cost of production and increase firms' profits. There is now a considerable body of empirical evidence that indicates the private sector research leads to productivity increases and economic growth. All of the studies so far are on the industrial sector. Several of the most recent studies using U.S. and French data are located in Griliches (1984).

The commodities which are researched will be major commercial commodities. One would expect the most private research on: (1) plantation crops and commercial livestock which used large amounts of cash inputs; (2) chemicals for major crops and regions; (3) hybrid crops in which a firm has property rights; and (4) export crops where there is oligopoly power in marketing or processing. This implies that there will be little private sector plant breeding on nonhybrid seed, little chemical research for subsistance and minor crops and little livestock research for noncommercial animals. At present, this means that many major food grains will be ignored by private breeders and this could skew income distribution toward commercial producers who already tend to be well off.

Most processors who do research will attempt to develop technology that will reduce the cost of production. Input supply companies should develop improved inputs which substitute for more expensive inputs. Both types of research should lead farmers to use less of the expensive inputs and more of the inexpensive inputs. In Asia the inexpensive input is usually labor and the expensive inputs are land and capital. Thus, one would expect local research to develop technology that is labor using. This would increase the demand for labor relative to other factors and ceteris paribus improve income distribution. The danger is that it is easier to modify capital intensive inputs from developed countries than to develop new labor intensive inputs. Thus, even if the technology is modified to fit local conditions and is more appropriate than technology which is imported, it could still reduce the demand for labor.

Private research may exacerbate regional and national income differences. It is most likely to concentrate on relatively favored regions which have transportation and irrigation infrastructure. However, some of the crops in which hybrids are becoming important are poor peoples crops - millets, sorghum and corn - and are still grown in poor regions.

## Technology Transfer

The major questions of importance to policy makers regarding technology transfer in developing countries are similar to the questions just asked regarding R&D. What are the determinants of the amount of technology transfer? What factors determine the type of techology transferred? Will the technology be appropriate? How much will it cost? What will the transfer do to income and income distribution? What will the transfer of technology do to the local ability to innovate?

The term technology transfer is used two ways in development literature: first, the transfer of technology between countries and second, the transfer of technology from the suppliers of technology within a country to the users of the technology. In this section we will be concerned primarily, with the first type of technology transfer.

Hayami and Ruttan (1971) identified three stages of technology transfer: material transfer, design transfer and capacity transfer. In the first stage material things - hybrid seeds, fertilizer, pesticides, etc. - are transferred through trade. The design transfer stage is characterized by the transfer of designs of factories or production facilities which allow the production of the hybrid seeds, fertilizer, etc. locally. In the third stage the ability to develop new products or improved production processes is transferred. In this stage R&D facilities are transferred.

The type, cost and quantity of technology transferred depends on the interaction of two groups - the transferer and the transferee in Asia, in other words the suppliers and demanders of technology. If the owner of the technology is a private firm, it tries to maximize its expected profits. These profits could be royalties from the sale of the right to use the technology, profits from exporting products which incorporate the technology, or profits from a subsidiary which produces products incorporating the technology. The firm is faced with decisions about which countries should receive the technology, by which means the transfer takes place, how much to sell and how much to charge for the technology. The firm's decision to introduce an innovation in any particular market is determined by (1) the cost of transfer, which is less than the cost of the original innovation but can be significant (Mansfield, 1982), (2) expected profits in the country to which technology is transferred, and (3) benefits that increase its profits elsewhere - i.e. germplasm that can be used elsewhere or increased profits to a chemical firm due to increased sales of active ingredients which allow the company to capture economies of scale in its home factories. Expected profits are a function of the same factors as the determinants of profits from research plus the ability of the company to take these profits out of the country.

The foreign firm that is supplying the technology has to decide which means of transfer will be most profitable to it. From the firm's standpoint the three stages require increasingly large investments and place the firm in an increasingly vulnerable position if the market does not turn out to be big enough or if there are political difficulties.

The implications are that foreign companies may not be very interested in trying to transfer technology to countries that have small potential markets unless the cost of transfer is very small. If the cost of transfer is very high, firms may hesitate to enter some large markets. The relative size of the cost of the transfer, the protential profits per unit and the potential market size will determine the desirability of the technology transfer to the firm and the bargaining power of the local company or government.

The institution in LDCs to which technology is transferred will have to chose the stage of technology and the type of technology within each stage on the basis of costs and benefits. The costs include the royalties and other payments to the owner of the technology, the R&D investment required to modify the technology to fit local conditions, the cost of teaching people how to use the technology and/or building production facilities to produce the technology and also the social costs (a consideration for governments but not for most firms). The benefits to the firm include increased profits due to cost reduction or sale of the new product and also future profits because of the increased technical capacity of the firm for future innovations. A government which is importing technology would consider the current and future profit to local firms plus the social costs and benefits from the technology.

How much technology will be transferred? Important determinants of the supply of technology will always be exogenous to the country which is importing that technology. These exogenous determinants include a firm's worldwide profits, information flows and policies in the firm's home country and the rest of the world. Policies that encourage research in major countries producing agricultural technology should lead to an increase in the supply of new technology aroung the world. For example the U.S. Plant Variety Protection Act has increased the supply of varieties in a number of crops. Other policies can discourage the transfer of technology although direct restrictions like the restrictions on exports of computer technology to the Soviet Union are difficult to enforce. The demand factors - market size, consumer preferences, input prices, etc. - are equally important in determining how much technology is transferred. These factors are more easily influenced by an LDC government than the determinants of the supply of technology.

There are few empirical studies that look specifically at trade in new technology. The induced innovation framework provides guidance on what type of technology will be demanded. However, there are few models to indicate the price, amount and type of technology that will be supplied by foreign firms. There are some case studies but these do not help identify determinants of the amount, type, direction (country) or cost of these technologies.

There have been some studies that have looked at the decisions companies make on whether to transfer technology through material transfer (exports) or through design transfer (usually joint ventures or local production by subsidiaries).

The evidence on the factors determining exports vs. local production indicates that tariff and nontariff barriers, the cost structure of the firms, availability of capital and the size of markets are important factors (Caves, 1982). Tariff barriers provide a clear incentive to production within the protected country. If the firm has a declining cost structure in the home country, it is less likely to invest in production overseas. Small markets are more likely to be serviced by exports than big ones.

Mansfield et. al. (1982) argue that the cost of transferring technology is high. He is talking about the design transfer stage in our framework. In the 26 industrial projects for which they have data, on average 19 percent of the total cost of the project was the transfer cost - things like training staff, cost of research personnel required while starting production. If these cost can be lowered, more technology should be transferred via design transfer rather than exports.

Studies about the location of TNC subsidiaries suggest the determinants of design transfer. These studies are important because most innovations developed by TNC's flow through subsidiaries rather than licensees. Therefore this is a major means of design transfer. Caves reviews the studies on this issue and suggests that "the distribution of foreign investment among countries as hosts depends strongly on their national characteristics relative to the countries that are principal sources of Multinational Enterprises. This proposition requires that information and its analysis to be quite costly to the firm and be accumulated largely through experience" (Caves, 1982:63). Davidson (1980) shows that U.S. companies in a number of industries typically invest first in Canada, then the U.K., West Germany, Mexico, Australia, etc. There is also a correlation with total GNP and GNP per capita but investment in countries that are similar like Canada, U.K. and Australia is higher than GNP and GNP per capita predict. Nankani's (1979) statistical study of foreign investement found that investment was higher between pairs of industrial countries and LDC's that formerly had colonial ties. Presumably the transaction and information costs were lower in these cases. It is apparent that these same costs would influence the direction of exports as well.

The question of the location of research by multinationals has been studied more than others. Behrman and Fischer (1980) on the basis of discussion with a large number of firms came up with the following list of factors which helped or hindered the location of research in a particular country. Three factors which induced firms to locate in a country are: (1) the existence of a profitable affiliate in the foreign country was the most important; (2) a growing and sophisticated market; and (3) an adequate scientific and technical infrastructure for doing research. Two obstacles were the economies of centralized R&D at home and the difficulties of assembling adequate R&D staff.

Mansfield et. al. (1982) have done the main statistical study on this issue. They found: (1) the higher the percentage of the firm's research conducted overseas, the higher the percentage of the firm's sales overseas; (2) higher overseas research was more closely related to sales from foreign subsidiaries than exports; (3) holding % of sales overseas constant, size of firm will be an important determinant of whether it can afford the mimimum scale of research that is necessary; (4) there were interindustry differences because of regulations and incentives from governments (more drug and chemical research was located outside the U.S. where there was less regulation); and finally the importance of differences in R & D costs was supported by the movement of research away from the U.S. in the 1950s and 1960s when foreign scientists were less expensive than U.S. scientists and the slowing of that trend as the differential disappeared.

Will the technology be appropriate? This issue can be broken down into supply and demand side questions. The supply side questions include: Is appropriate technology available from foreign countries? Will the owners of the technology supply it? In many third world countries there is the fear that companies will not provide the most appropriate technology because the country does not offer a large enough potential market or that there are political barriers like the U.S. restrictions of high tech. exports to Communist countries.

Another possibility is that local companies or government institutions do not actually have incentives to demand appropriate technology from external sources. Local companies or government institutions may not be receiving or following the appropriate price signals. Stobaugh and Wells (1984) suggest that the more competitive the industry, the more appropriate the technology adopted but there is still a tendency to adopt technology that is too capital intensive. In many cases firms do not face input prices that represent the true scarcity value of the inputs due to government policies or market imperfections. In addition local firms may not have sufficient information about what foreign technology is available. Government institutions may be faced with the same problems of inappropriate prices and insufficient information. In addition they may have political objectives which cause them to chose inappropriate technology. In the case of local subsidiaries of multinationals the choice of technology may be influenced not only by local profit opportunities but also profits of the home company.

Cost of technology will depend on supply and demand side factors. The supplying firm will consider its costs of transfer, its market power, and its estimation of the value of the technology to the buyer. The buyer will consider the value of the technology, the cost of alternatives and the information that comes with the technology. The price will be some sort of compromise.

The impact of technology transfer on agricultural productivity in market economies has in most cases been positive. There are many examples of the positive effects of technology transfer and few examples of cases where technology transfer substantially slowed the growth of agricultural productivity. The reason is that in a market economy the technology would not be transferred and diffused unless it was increasing productivity or meeting some consumer demand. Where inappropriate technology has been adopted for a long period of time, markets often are not used to allocate resources as in some socialist countries or prices are distorted by government policy.

The impact of new technology on income distribution is subject to great debate. There are always sectors of the economy that are left out or displace by technical change. In the induced innovation framework, technology allows the replacement of expensive inputs with less expensive ones. The owners of the inputs displaced will have their relative incomes reduced. This will worsen the income distribution of the economy only if the induced innovation mechanism does not work.

There has been considerable discussion but little empirical research on the impact of technology transfer on the local capacity to innovate. There is a close relationship between transferring technology and R&D. A firm that does the R&D will do more research if it expects to sell the technology to more countries. For the firm to which technology is transferred, the process of searching for technology and adapting it to local conditions develops the skills that are required to do research. These skills make research cheaper and more likely at a later stage in their development. In addition since most R&D conducted by private industry in developing countries is to adapt technology developed in other countries, importing major technologies from other countries may increase the opportunities for adaptive research and lead to more R&D. The best empirical evidence on this issue is Mikkelsen (1984) who finds a positive relationship between the availability of foreign technology and the amount of private research Philippines firms conduct.

## Policy

The primary aim of government technology policy in developed economies is to encourage technology that will promote the most rapid growth of GNP. A closely related aim is to maintain or improve the countries competitive position in international markets. In recent years a number of other goals have been added. Reducing the negative environmental impacts of new technology and reducing the labor displacing affects of technology are two goals that have had particular impact on agriculture.

The basic economic justification for government action in this area is the argument that insufficient research will be carried out by the private sector because it cannot capture a large enough share of the benefits. It appears that a similar idea is behind much government policy on technology transfer - insufficient technology is transferred because firms cannot capture much of the social benefit from research. There is much less empirical evidence to support this than to support the argument for government intervention in research. There are usually other arguments for government intervention in technology transfer, e.g. inappropriate technology and its impact on income distribution, that help strengthen the political case for intervention.

In the U.S. there is a substantial body of literature on technology policy. Almost all of it relates to industry rather than agriculture. Nelson (1982) edited a useful book of case studies which looks at the relationship between government and technological change in a number of industries including agriculture. He identifies two sets of technology policies that the U.S. government has used. The first set are government R&D support programs which include: (1) those associated with public procurement or other well-defined public objectives like support for aviation research by the Department of Defense, (2) those that involve an extension of support of scientific basic research to support of research to advance generic technological knowledge, (3) programs that are aimed at meeting reasonably well-defined clientele demands, and (4) attempting to support "winners" in commercial competition. The second set of policies do not involve direct R&D support. The central policies include government procurement, regulation, antitrust and patent policy.

Nelson concludes that in the U.S. there are some areas of research that may be overfunded or at least have sufficient funding. Therefore "the design of appropriate government policies requires mechanisms to identify the particular kinds of research, and sometimes that particular projects that are being underfunded. Therein lies the problem. Government agencies are seriously constrained in the information they are able to marshal directly or indirectly to guide the allocation of public R&D monies.

The historical experience canvased in this volume suggests that there are three potentially fruitful routes that can be followed. One is to associate government R&D support with procurement or other well-defined public objectives. A second is to define and fund arenas of nonproprietary research and allow the appropriate scientific community to guide R&D allocation. The third is to develop mechanisms whereby potential users guide the allocation of applied research and development funds. A fourth kind policy, in which government officials try themselves to identify the kinds of projects that are likely to be winners in a commercial market competition, is seductive. The evidence collected in this volume and other studies suggests, however, that this is a strategy to be avoided." (Nelson, p. 481)

There is one quantitative study of the relationship between government research and private sector research (Mansfield, 1984). It indicates that in the U.S. industrial sector, government research induces more private sector research instead of substituting for private research. There is substantial literature on the high social rates of return to government agricultural research (Ruttan 1983) but no quantitative evidence of its effect on private research. In recent years in the U.S. there has been some inconclusive discussion of the impact of the R&D tax credits. Kamien and Schwartz (1982) reviewed the many studies on the impact of firm size and industry structure on R&D expenditure, but there is little evidence on the effectiveness of government antitrust policies on innovative behavior of firms. There is a large body of literature discussing the optimal patent policy and growing body of literature on plant variety protection acts (Butler and Marion, 1983).

Much of the work on technology policy in developing countries has been reviewed in Stewart (1979). He suggests that the original goal of technology policies in LDCs after independence was to maximize the inflow of technology. However, when this flow of technology did not cause the expected growth of per capita income, countries changed their goals. Now countries want:

1. to reduce the cost of technology transfer
2. independence of decision making
3. development of local technological capacity
4. appropriate technology which in most cases means more labor intensive technology.

I would suggest that in recent years some developing countries are starting to add environmental concerns and worker safety to this list of goals.

Stewart has also listed policy instruments that developing countries use to try to reach these goals. He notes that the "relevant policies vary with the stage of development and particularly the technological and administrative capacity of the country concerned." He lists the following:

(1) policies aimed at improving the terms of technology transfer by controlling the size of royalties and terms of agreements;

(2) general economic strategy of the country;

(3) policies to reduce the packaging element in imported technology (technologies that come as part of a wholly owned subsidiary are the most packaged while technology that is sold in the form of a machine is not packaged at all);

(4) tax incentives;

(5) policies like tax incentives, import controls and local R&D to protect and promote local technological developments which he suggests are rarely effective on own but can be effective in a package;

(6) patents;

(7) local technological capacity which is of critical importance: "it is a vital part of the develoment process, it is necessary for independence, to improve bargaining power in relation to the import of technology, and to generate appropriate technical change;"

(8) promotion of appropriate technology through supply and demand sides: (a) demand - determinants of income distribution and consumption patterns, trading strategies, control of investible resources and relative factor prices, (b) supply - collection and diffusion of information about available technologies; local R&D; international institutions to transfer technology.

The World Bank conducted a series of industry case studies that attempt to look at the relationship between government policy and technology in developing countries. The results of this are summarized in Dahlman and Westphal (1984). They suggest one basic principle that minor innovations are very important because their cumulative impact can lead to productivity increases greater than those initially possible from major innovations.

They believe the government has an important role to play in technology policy. They list the following types of policies as particularly important. First are general policies that allow market forces to operate. Second are policies to improve the choice of technology, like subsidies for information collection and dissemination. Brazil and Mexico have data banks and subsidize feasibility and engineering studies. Also the government may be able to get rid of price distortions which lead to in appropriate choices. Third are policies to prevent foreign firms from abusing monopoly power over certain new technology. These policies include controls on price and terms of technological transfer. Dahlman and Westphal believe that such policies have helped but it is not clear how much. Fourth they find that government R&D is important but government R&D on major innovations is usually inappropriate unless the institution has to generate its own revenue. In that case the research will be more demand driven and the technology has a chance of being useful.

The literature on technology policy for the agricultural sector in developing countries is very limited. Most of it has focussed on the need for public sector research (see Pinstrup-Anderson or Ruttan 1982). There have been a few papers written about patents and similar legal devices like plant variety protection laws (Evenson, Putnam and Evenson, 1983). There are very few empirical analyses of the relationship between government policies, technology transfer, private research and productivity growth.

There is one group of studies underway in Latin America on private sector research in the agricultural sector. This series of case studies which was funded by ISNAR looked at the relationship between government agricultural research and private sector research investment. Pineiro and his associates found that there were cycles, of agricultural development (Jacobs and Obshatko, 1985). During the first cycle agronomic techniques are the major force behind growth and these are primarily produced by the public research system. During the second cycle new technology is embodied in inputs from the industrial sector. Therefore, much of the technology is developed by private companies in the industrial sector. They suggest that the government may have to play an active role in ensuring a supply of the needed inputs at an early stage of development. Whether the country imports the needed technology or produces it internally depends in part on the level of development of the industrial sector in the country.

Within the second stage they also examine the relationship between government and the private sector in specific industries. The Argentine and Brazilian private seed industries were based on technological breakthroughs of public sector research. They also examine the plant breeders rights laws and find that they are not enforced and thus had little impact (Jacobs, 1985). In the tractor industry government protection and credit to farmers shifted the industry from imports to local production. However, the protected market and government tolerance of an oligopoly of firms also led to stagnation in technology. In recent years with the decline in protection, technology has started to catch up with the rest of the world again (Nestor, 1984).

Pineiro's model of agricultural development has important implications for public sector research. Historically in Latin America public sector research preceded and provided the basis for the technology embodied in inputs which induced private research. This seems to imply that public sector research is a necessary condition for further agricultural development. In the second cycle private sector research and extension activities start to grow and place pressure on public research. The private sector hires away many of the scientists from the public sector. It starts to erode the political support for government research because some influence groups no longer directly depend on the public research system for inputs.

The following policy issues need to be examined in more depth in the next two phases of this project: (1) Does govenment research crowd out private research or is it an incentive to more private research? (2) What type of agricultural research should the government be doing? (3) Do policies that restrict "packaging" of technology and the import of technology reduce growth? (4) What is the economic payoff to tax incentives and policies like patents that promote private sector research? (5) Do patents or lack of patents have any affect on productivity growth? (6) What are the costs and benefits of unrestricted imports of technology?

## III. Private Sector Technology Transfer and Agricultural Research in Asia

The private sector has played a very important role in transferring agricultural technology to Asia. However, it is difficult to get data on the amount technology transferred. The most readily available data is trade data which indicates the amount and value of transfer at the "material" stage. Table 3 contains data on the value of U.S. exports of inputs in which U.S. technology is embodied to Asia (excluding Japan and China). Fertilizer and agricultural machinery were the largest export items followed by pesticides, live animals which were primarily for breeding, poultry in the form of eggs and day old chicks, and seeds. Table 4 indicates the total imports and exports of tractors, fertilizers and pesticides in selected Asian countries. Fertilizer is by far the most important followed by tractors and pesticides. Table 3 and Table 4 indicate that fertilizer imports have declined in recent years. Total pesticide imports have increased while the U.S. sales declined. Tractor imports declined, but total agricultural machinery imports may have continued to increase.

Technology transfer at the design stage is the transfer of production facilities. The private sector has played a very important role in technology transfer of this type. Companies from OECD countries have invested in production facilities in most input supply industries and many of the processing industries of Asia. In most cases the production facilities that they built used technology that was new to the country if not the latest in the world. In some industries where the government owns the production facilities the private sector sold the government the technology and built the facility. In other cases the private sector sells the knowhow to a private company in another country and receives a royalty or lump sum payment for this technology.

Table 3. U.S. Exports of Agricultural Inputs to Selected Asian Countries. 1965-1983 (in 1000 dollars).

| | 1965 | 1970 | 1975 | 1980 | 1983 |
|---|---|---|---|---|---|
| Seeds | -- | 2183 | 1315 | 3067 | 4598 |
| Poultry | -- | 778 | 2278 | 7002 | 7619 |
| Livestock | -- | 369 | 2824 | 7897 | 18,979 |
| Fertilizer | 146,656 | 113,002 | 532,031 | 575,093 | 428,689 |
| Pesticides | 13,008 | 12,795 | 41,291 | 82,070 | 68,770 |
| Agricultural Machinery | 55,924 | 68,247 | 205,511 | 254,928 | 377,581 |

Source: USDA/FATUS.

Selected Countries are:

- Bangladesh
- India
- Pakistan
- Indonesia
- Malaysia
- Philippines
- Thailand

Table 4. Selected Asian Countries Exports and Imports of Agricultural Inputs, 1965-1982. (millions U.S. $)

| | | 1965 | 1970 | 1975 | 1980 | 1982 |
|---|---|---|---|---|---|---|
| Tractors | | | | | | |
| | I | 55 | 72 | 149.4 | 291.6 | 288.2 |
| | E | .3 | 2.6 | 1.7 | 4.4 | 1.9 |
| Fertilizers | | | | | | |
| | I | 143.9 | 177.6 | 1460.7 | 2200.0 | 1141.7 |
| | E | 2.7 | 4.1 | 4.8 | 41.1 | 29.1 |
| Pesticides | | | | | | |
| | I | 24.6 | 59.6 | 138.0 | 197.9 | 240.0 |
| | E | 1.3 | 1.9 | 2.7 | 13.8 | 12.8 |

Source: FAO Trade Yearbooks.

Note: I and E are Imports and Exports.

Fertilizers: crude + manufactured.

Selected Countries - see Table 3.

There is no readily available measure of the quantity and value of this type of technology. Royalties and payments for technology would be a useful number but this type of data is rarely available or if it is available for the economy as a whole the agricultural portion is rarely identified.

One measure of the importance of foreign technology is the ownership of production facilities. The seed industry of most Asian countries is dominated by the government. Much of the seed processing equipment used in the early years of the industry in Asia was imported from the U.S. but now it is produced locally in many countries. In the part of the seed industry producing hybrids foreign companies are starting to play an important role in the Philippines and Thailand.

The formulation of pesticides and the production of technical material for pesticides is dominated by multinationals in most countries of except India. Even there companies affiliated with the Multinationals produce the majority of the technical material used to make agricultural pesticides. The government has played a larger role in the production of fertilizers but the governments have usually purchased the technology for their plants from private foreign companies (Ghatak, 1981).

It seems that the multinationals have not played an important role in the transfer of agricultural machinery technology in recent years. Most tractor companies in Asia purchased or licensed technology when they started production. However, there appears to be little transfer of technology to this industry in the last decade. The new process or product technology appears to have come from Asia.

It is possible to identify many of the industries which are doing research in Asia and to provide some impressions of the trends in their investment in agricultural research. As yet we do not have sufficient data to quantify the amount of research. These impressions are based on interviews with companies in the U.S. and a few Asian companies plus our review of the literature and previous research. We will try to confirm these impressions in Phase II of this project.

The input supply industries represent the fastest growing area of private research. Of field crops hybrid corn is attracting the most private sector research investment. At least four companies are developing corn hybrids in tl Philippines. Six to eight companies are developing hybrids for Thailand. The goal of research in both of these countries is to develop high yielding hybrids that are resistant to downy mildew. Research is being done on hybrid corn, sorghum and millets in India, hybrid corn and sunflower in Pakistan, and hybric rice in the Philippines.

Agricultural research by chemical companies in South and Southeast Asia ha grown from almost nothing in 1970 to a number of small programs of applied research at present. In company terminology almost all of the research in developing countries is considered "development" rather than research. In 1970 a number of companies ran field trials in Asia but there were only a few experiment stations. Research on rice was frequently carried out at stations in Japan. By the early 1980s most major multinational agricultural chemical companies had stations in tropical Asia. Those that did not have their own stations increased their research by using land rented from farmers or estates. Examples of this expansion include ICI which had no field stations in Asia before 1970 but by 1978 had developed field stations in India, Malaysia and the Philippines. Ciba-Geigy established its plant protection research on tropical rice in Indonesia and is about to open another station in Malaysia. American Cyanamid established a research program in the Philippines.

The actual research carried out in Asia is very applied. Applied research on new chemicals included tests of the most effective rates of their application and different systems of application. The companies do the trials that are required by governments to get certification and/or pay universities or individual scientists to do these tests. They also do research which attempts to find pesticides that can be mixed with a company's main product to solve new problems.

Little formal research is being done on agricultural machinery but a lot of innovative activity is taking place. In the Philippines 23 of 55 farm machinery firms surveyed in 1981 were able to estimate their R&D expenditures even though only a few of these firms had formally designated R&D personnel with a separate R&D budget (Mikkelsen 1984:44). When asked how many personnel participated in inventing new products, improving products and improving production methods, 55 of 56 firms reported personnel involved in at least one of these activities. In India four large scale agricultural machinery firms reported annual research expenditure of almost a million U.S. dollars each in 1978-79 (India, 1980). Continuous innovation by small scale manufacturers of farm equipment for cultivation and seeding, irrigation equipment, threshers and other machinery is taking place in India and Thailand.

We have no quantitative evidence on the trend in innovative activity in farm machinery. It seems to have followed the growth in sales of the industry. Thus as the industry grew in the 1960s and 1970s innovative activity grew along with it.

Private companies in developing countries do not seem to do much poultry breeding whether they are local companies or subsidiaries. This is due to the fact that Western poultry technology is easily adopted in a wide range of environmental conditions. It is also due to the fact that U.S. breeders can replicate the conditions that birds will face in developing countries. Although little breeding has taken place, there has been more interest in private R&D on feed mixes both in Thailand and in the Philippines. In addition, improvements occurred in management techniques and building design. These were done locally but were not reported as R&D.

Research by the processing and marketing industries has been going on for a longer period of time and has not grown as rapidly as research by input-supply firms. Tobacco companies invest in applied research and extension in Bangladesh, Pakistan, India, the Philippines and Thailand. The research has primarily consisted of testing different varieties and production practices for yield and leaf quality, but there has also been some research on inexpensive substitutes for wood as fuel in the flue curing. The trend in investment is not clear. Sugarmills invest in research in the Philippines, Pakistan, and India. As in the case of tobacco, their research consists primarily of testing varieties bred elsewhere and developing better management practices. As yet there is no quantitative evidence, but the trend in research by sugarmills appears to be downward.

Research on rubber, oilpalms and coconuts is being carried out by private companies in Malaysia and to a lesser extent in Thailand and the Philippines. In Malaysia at least three of the major plantation companies are working to develop superior oilpalm varieties using tissue culture. Some of the new varieties are already bearing fruit. Rubber research was also conducted by companies in Indonesia until 1965.

Major banana and pineapple operations have grown rapidly in the Philippines and Thailand over the last 20 years. Much of this expansion has been due to acreage expansion, but there has been some applied research to find out what varieties and cultural practices work best in these countries.

In some cases the commercial feedmills or corn processors are large companies which have contract growers to produce corn. These large companies provide technology to farmers by breeding corn or buying improved varieties from overseas. San Miguel in the Philippines and Rafhan Maize in Pakistan are examples of millers and processors that do corn research.

## IV. Industry Case Studies

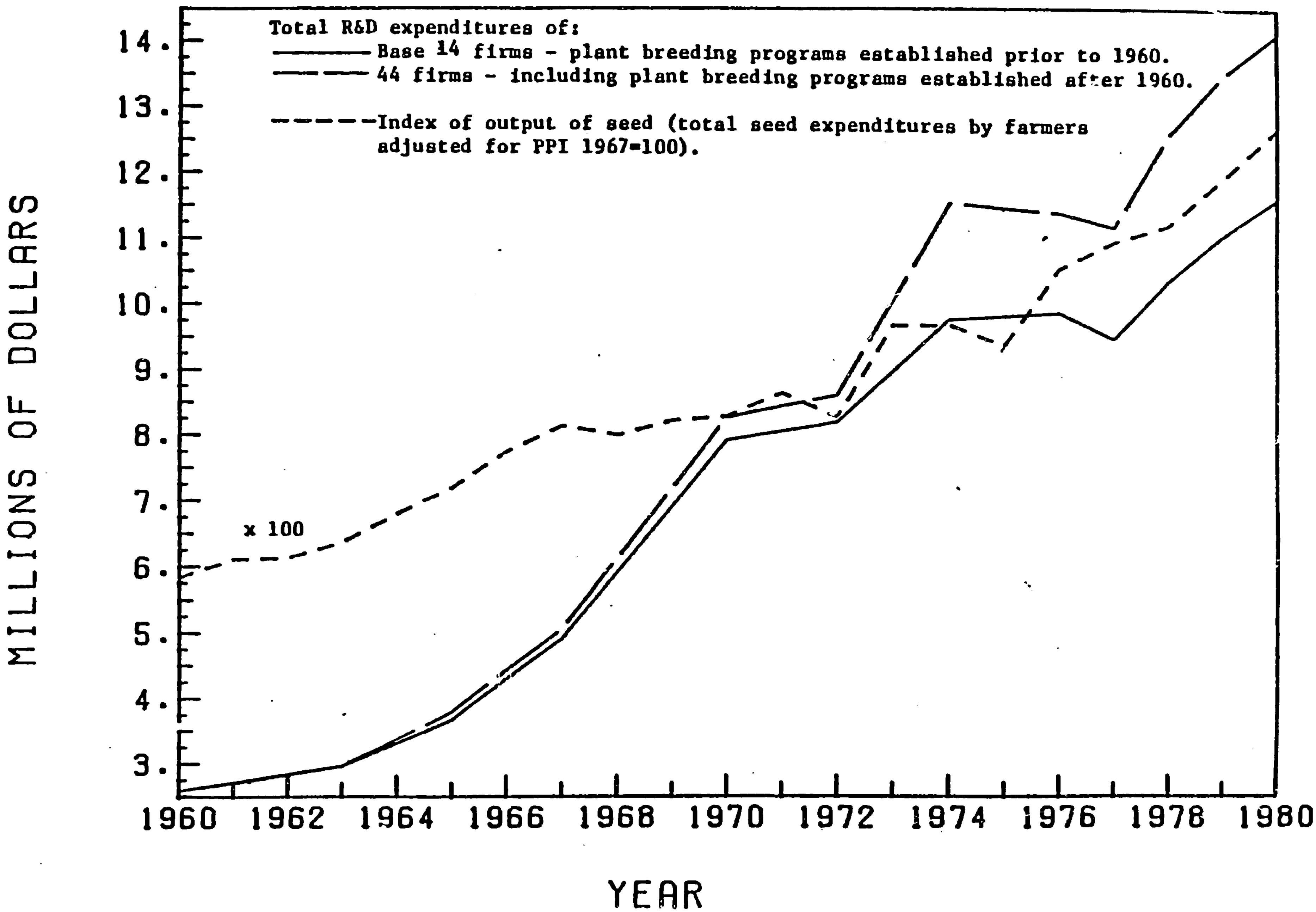
A major part of the supply of new technology in developing countries is from private companies based in the U.S. In the previous section, I described the size and areas of the private sector participation in technology transfer and research. However, this does not indicate the ways in which these companies make decisions to supply technology. A framework for understanding their decisions was described in section II. In order to test the applicability of this framework and better understand firms' decision making we have described in more detail the development of three industries - seeds, pesticides, and commercial poultry - in the U.S. and then the expansion of these industries in the third world. We will not consider the two other important industries - agricultural machinery and food processing - in this report. We will examine them in Phases II and III, however.

### Development of U.S. Seed Industry

History of the seed industry in the U.S. supports some of the theoretical arguments from section III. Before 1930 it was a competitive industry made up of many small firms with no institutional arrangements to provide property rights to the inventor. There was little incentive for individual firms to invest in research. The result was that little research was done by the private sector.

The rapid growth of research by private seed companies and changes in their priorities emphasize the importance of property rights in increasing research. The development of hybrid corn by scientists at the state experiment stations led to a dramatic increase in research by private companies (Griliches, 1958). Hybrid corn made research an attractive investment for two reasons. First, because the corn produced by the hybrid would not give high yields the second year, it could not be used again by the farmer or sold by the farmer to his neighbors. Second, it was not easy for other firms to copy the hybrids because

I ure 1. Private Firm R and D Expenditures (I :ed) and Output Index for Seeds, 1960-1980.




34a

it would take a number of years to work backward from the hybrid to the inbred lines which made up the commercial hybrid and by that time the original company would have released better hybrids. Thus, seed companies could make enough money selling hybrids to profit from research on hybrid corn.

Seed companies expanded their research into other crops and commodities when they had this type of protection. After developing the market for hybrid corn they turned to poultry and sorghum. They applied the same principles of hybrid breeding to these commodities and were able to duplicate the success of corn. The next area of research was hybrid wheat in the late 1950s and early 1960s. Almost all major seed companies started to invest in research on hybrid wheat. Wheat unlike corn and sorghum is not a naturally cross pollinated crop and is genetically more complex than corn and sorghum. It was not possible to develop a successful hybrid wheat variety in the U.S. until the release of Bounty by Cargill in the 1980s. By that time most companies had become discouraged with hybrid wheat and dropped out or dramatically reduced the size of their programs.

The next shift in research priorities and aggregate research expenditure came in the late 1960s and 1970s. This included a shift into new crops especially soybeans. This shift seems to have been due to the Plant Variety Protection Act and increased demand for the crops. The Plant Variety Protection Act gave firms the right to exclusive sale of varieties that they developed. Farmers are allowed to keep their own seed and plant it the next year, but they are not allowed to set up their own seed business to sell this variety. Since most farmers buy new soybeans each year there is a substantial market for soybean seed. The combination of legal protection and a large market led many companies to invest in soybean research.

As suggested by theory, research in the seed industry is closely related to sales. Figure 1 shows that from 1960 to 1980 research has followed the trend of seed sales. The research expenditure in the early 1960s is higher than the figure shows because some companies which were doing research then have gone out of business and were not counted in the survey of present firms upon which this figure was based. Before 1960 research expanded rapidly as hybrid corn spread in the late 1930s and the 1940s according to discussions with private firms.

Most seed companies started their international operations in the 1950s in Europe and the 1960s in developing countries. The reason for this expansion seems to be a combination of several factors. First, there was the perception in the 1960s that growth of sales in the U.S. market - particularly for hybrid corn - was slowing down. Second, companies saw that there were large markets in the rest of the world where they could sell their seed. This shift from a U.S. to an international market led to changes in research priorities. Companies started to breed corn for resistance to tropical pests and for local market characteristics. They also began to establish research stations outside the U.S. as the most efficient way of developing the needed varieties.

Issues of market structure

In a study of 51 seed companies Butler and Marion (1983) concluded that there is relationship between firm size and research expenditure. However, there is no evidence of a positive relationship between firm size and research intensity.[1]

Some observers have worried that increased concentration will lead to less research. There is no evidence that the increase in concentration in this

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1 Research intensity is defined as research expenditures divided by sales of the company.

industry has decreased research intensity. Total research investment by the private sector has clearly increased. The industry still is not very concentrated by some measures - there are hundreds of seed companies and the four and eight firm concentration ratios are not particularly high. There has been some concern about the high price of hybrid seed which some critics believe is maintained as a result of industry concentration. We have seen no evidence that concentration has reduced investment in research.

There is no evidence that the purchase of seed companies by chemical, pharmaceutical and food companies has led to a decline in research. One company reported that it had more resources for research after it was purchased by a pharmaceutical firm but others reported no change. The firms interviewed also reported that the synergy between the more basic biological research of the parent firms and the seed research has not taken place as yet.

Most firms reported no major shift in research priorities when they were purchased. Funk was one company that reported some change. It was purchased in 1962 by CPC International, a large multinational food firm. CPC wanted them to produce hybrids with high oil content. Research resources were shifted to meet this goal. However, CPC was disappointed with the high oil varieties and sold the company in 1972. In 1974 it was purchased by Ciba-Geigy which wanted a successful general corn company. Their priorities are now set by the general needs of U.S. farmers for high yielding hybrids. Another example of a shift in priorities is DeKalb's hybrid wheat program which was sold to Monsanto. It greatly increased the program to develop hybrids using Monsanto's gametocide rather than cytoplasmic male sterility.

Critics of these mergers cite the example of breeding varieties for resistance to the parent company's herbicide. Herbicide resistance is frequently controlled by a single gene. This is one of the easiest characteristics to select for using the new biotechnology. Thus, it is not clear whether research on this characteristic is due to the purchase of seed companies by chemical companies or due to the new techniques available because of changes in science.

## The relationship between public and private sector research

Private sector breeding developed into its current form because of the development of hybrids by scientists at U.S. universities and government agricultural experiment stations. The relationship between the government and private sector continues to be very close. In recent years even in the seed corn industry in which there is the most private research, 50 percent of the hybrids in commercial use contain at least one public sector inbred (Ruttan, 1983).

Private sector breeding has grown rapidly in the last 15 years while the public sector has been about constant in size. The latest figures indicate that there were 435 Ph.D. and 268.5 MS plant breeders working on corn, sorghum, soybeans and wheat in the private sector (Kalton and Richardson, 1983) and 494 Ph.D. and MS plant breeders working on all crops for the USDA and state experiment stations (USDA, 1983).

The large seed companies have been pushing the government to stop releasing varieties and inbred lines and concentrate on basic research. This has had some effect in recent years - USDA is shifting its resources from breeding to more basic work. Most public sector plant breeding is being carried out by the state experiment stations and they do not seem to be reducing the amount of resources going to breeding.

## Technology transfer

The U.S. seed industry started to go into the Third World in the late 1960s. Before that most of the major firms had been too busy expanding in the

Table 5. U.S. Seed Trade, 1965-1984
Quantity (MT) and Value ($1,000) exported (X) and imported (M) by continent.

| Continent | Trade | 1965 Q | 1965 TV | 1970 Q | 1970 TV | 1975 Q | 1975 TV | 1980 Q | 1980 TV | 1984 Q | 1984 TV |
|---|---|---|---|---|---|---|---|---|---|---|---|
| World | Export | 22,983 | 13,063 | 40,751 | 36,060 | 116,904 | 116,195 | 199,762 | 247,311 | 252,363 | 325,862 |
| | Import | 81,764 | 15,262 | (147,267) | 23,995 | (21,873) | 43,952 | (42,107) | 56,267 | 81,928 | 96,542 |
| Latin America | Export | 4,405 | 2,364 | 6,179 | 8,021 | 18,265 | 33,174 | 67,517 | 70,589 | 77,716 | 94,782 |
| | Import | 4,448 | 990 | (5,307) | 1,908 | (3,800) | 6,822 | (na) | 10,411 | 7,600 | 19,027 |
| Europe | Export | 9,742 | 5,853 | 14,329 | 12,761 | 38,333 | 38,741 | 67,943 | 88,992 | 70,849 | 92,193 |
| | Import | 8,865 | 5,600 | (2,878) | 3,581 | (700) | 13,359 | (456) | 11,311 | 7,545 | 19,864 |
| Asia | Export | 1,232 | 694 | 8,606 | 5,841 | 18,233 | 14,318 | 27,361 | 38,142 | 64,755 | 89,032 |
| | Import | 57.6 | 128 | (1,214) | 2,171 | (1,500) | 4,744 | (2,088) | 10,734 | 5,283 | 21,134 |
| Canada | Export | 5,824 | 3,499 | 9,865 | 7,477 | 31,200 | 22,483 | 29,201 | 34,234 | 27,528 | 29,907 |
| | Import | 76,081 | 8,516 | 137,630 | 15,844 | 14,473 | 16,707 | (39,358) | 19,463 | 55,071 | 28,636 |
| Africa | Export | 754 | 379 | 692 | 792 | 7,230 | 4,142 | 4,201 | 6,367 | 7,661 | 12,564 |
| | Import | 272 | 28 | (na) | 195 | (200) | 618 | (na) | 2,575 | 5,396 | 5,290 |
| Oceania | Export | 1,026 | 724 | 1,080 | 1,167 | 3,643 | 3,237 | 3,593 | 8,897 | 3,424 | 6,075 |
| | Import | - | - | (238) | 296 | (1,200) | 1,702 | (205) | 1,773 | 1,123 | 1,967 |

(NA) Not available
( ) Incomplete

Source: USDA/FATUS

U.S. market to bother developing foreign markets. There were a few exceptions to this rule like Cargill's Argentine seed company in the late 1940s and DeKalb's program in India in 1960. The motivation for the general move into foreign markets was the expected slowing in growth of the U.S. market. Also the mergers of U.S. companies with large food companies and chemical companies that have a more international outlook may have had some impact on their expansion.

The firms we interviewed emphasized the importance of market size in their decision to transfer technology. They are willing to sell their hybrids to anyone who has the money to buy them. If they decide to make a major marketing effort, go into a joint venture, start producing the seed in a country or doing research there, they study the market prospects closely. All major companies assess the future size of the market and the infrastructure of the seed industry. Then they examine other factors. They look for problems of repatriating profits or gaining other benefits such as useful germplasm and winter nurseries. They also consider the cost of setting up business - how much research would be required to develop a hybrid or variety that fits the major markets of the country. One futher consideration is the probability that they would lose control of their proprietary lines to competitors.

The seed industry transfers technology through commercial varieties, germplasm and information. Companies export varieties from the U.S. and other countries if the varieties or hybrids fit into the agriculture of the other country and there are no official barriers to entry. They transfer elite lines and scientific information to countries where they have breeding programs, joint ventures with other firms that have breeding programs or licensing agreements with firms that breed crops. The new information may consist of new breeding techniques or new basic knowledge about the crop.

The size of seed exports from the U.S. is large (see Table 5). Most exports go to Europe but Latin America and Asia are now major markets also.

The cost of establishing a seed subsidiary is reduced if the parent company already has a subsidiary in county - e.g. Funk moving into Thailand where there is an active Ciba-Geigy subsidiary. In other cases the seed company has led the way - Cargill in Brazil.

A yield enhancing or cost reducing technology like biological nitrogen fixation in corn which was developed in the United States and could be embodied in hybrid seeds would probably first be used commercially in Argentina, then Europe or South Africa, and then to Thailand. It would move first to Argentina because the agroclimatic conditions are similar to the U.S., the major companies have subsidiaries there, and it is a large market. The one thing that might remain a barrier is if Argentina continues to favor flint-type corn instead of dents. If this continues, the new characteristics would have to be bred into the flints which would take a few extra generations. All of the conditions that apply in Argentina apply in France. The only difference is that France has a strict plant variety protection act which increases the time it takes to introduce a new hybrid from two to five years according to the companies that we interviewed. Transfer to Thailand might take longer because the new characteristic would have to be bred into tropical hybrid which have different characteristics than U.S. hybrids. In addition the market may not be as big as in Latin America or Europe.

The seed industry in Asia

The public sector does most of the research and provides most of the new seed varieties in Asia. There are few private firms that are large enough to capture a large share of the market and there is no legal protection, like plant breeder's rights, which would allow companies to capture sufficient benefits to

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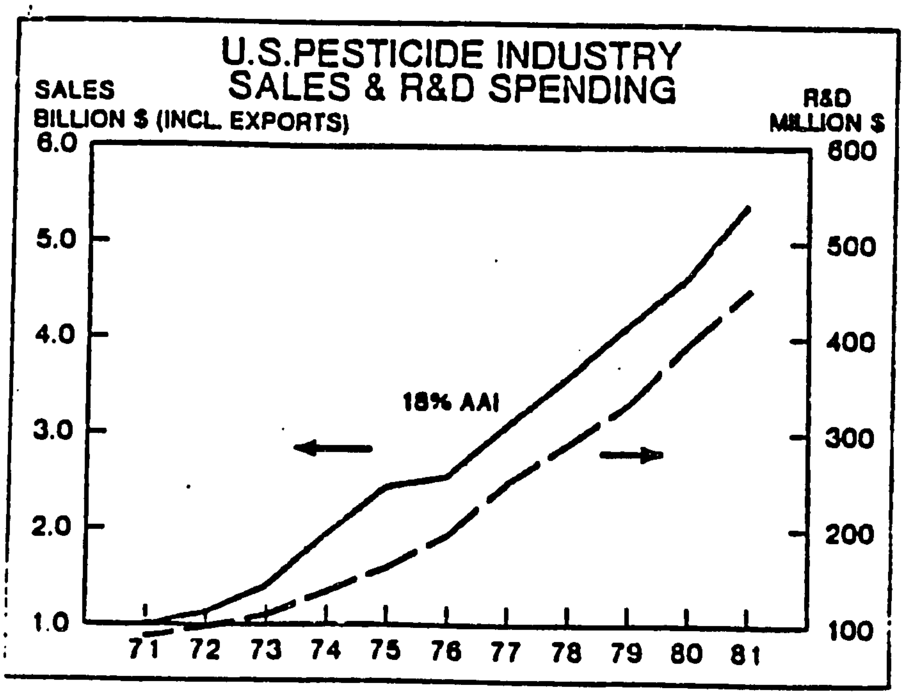
Figure 2




Source: Pliska, 1983.

justify research.

Private investment in plant breeding has increased over the last decade in several countries in South and Southeast Asia. Like the U.S. public sector research breakthroughs provided the basis for private sector research in the seed industry in the Third World. In Southeast Asia the public sector made two key breakthroughs which made it possible to control downy mildew in corn. The first was the identification of genetic resistance to downy mildew and the second was the development of seed treatment. The hybrid seed industry in the Philippines and Thailand followed this development. In India the government research system developed hybrid corn, pearl millet and sorghum in the late 1950s and 1960s. In the 1970s the private sector started to breed hybrids of these crops. Some research is being done on hybrid sunflower in Pakistan, and hybrid rice in the Philippines.

Three types of seed firms do research in Asia. First, a few Asian firms have developed their own research programs without any foreign collaboration. Second, Asian firms have established joint ventures with foreign seed companies. Third, foreign companies have established wholly-owned subsidiaries. The second arrangement appears to be the most common. Only a few Asian firms have their own, completely independent research program and only a few Asian governments have allowed wholly owned subsidiaries. In Southeast Asia the firms which do research or have joint ventures with foreign firms are large firms which specialize in other products besides seeds. In South Asia both large multiproduct firms and some companies that only sell seeds are doing research.

Several of the large firms in Southeast Asia are expanding their operations from their home country to other countries in Southeast Asia. Charon Pakporn from Thailand is expanding into Indonesia and China and San Miguel is also trying to move into Indonesia.

Table 6. Pesticide R&D Expenditures as % of Total Sales by Size of Company

| Year | Small | Medium | Large | Total |
|---|---|---|---|---|
| 1970 | | | | 9.7 |
| 1975 1/ | 20.8 | 9.5 | 5.4 | 6.7 |
| 1976 1/ | 29.0 | 11.2 | 6.9 | 8.3 |
| 1977 2/ | 20.4 | 13.2 | 6.7 | 7.9 |
| 1978 2/ | 17.4 | 11.1 | 7.3 | 8.1 |
| 1982 3/ | 18.0 | 10.8 | 9.1 | |
| 1983 3/ | 25.4 | 10.3 | 11.9 | |

1/ Categories: small ($10M), medium ($10-100M), large (over $100M).
2/ Categories: small ($15M), medium ($15-100M), large (over $100M).
3/ Categories: small ($50M), medium ($50-200M), large (over $200).

Source: National Agricultural Chemicals Association

## Development of the U.S. Pesticide Industry

The chemical pesticide industry is fairly young. Although chemicals have been used on fruit and vegetable crops since before the turn of the century, the rapid growth in use on field crops dates from the 1940s when the insecticides DDT and BHC were introduced. This was followed by the rapid growth of herbicides in the 1960s and 1970s when they surpassed insecticides in amounts used.

The chemical industry in the West has been able to appropriate a sufficiently large share of the benefits which farmers derive from the use of agricultural chemicals to profit from their investments in agricultural research. They have done this using a combination of market power, patent protection, trade names and trade secrets.

Research expenditure has grown with the growth in sales. Since the late 1960s, research has been about eight percent of the value of sales (Figure 2). Within the industry there has been some change in research investment. The cost of research has gone up considerably in part because more research is required to get a new product registered. This has led to an increase in research by some firms. These registration requirements also mean that it takes longer to bring a new product to market. As a result, the length of the patent protection has been reduced. These changes and companies' assessments about the slow growth of markets in the future led some chemical companies to stop producing agricultural chemicals entirely.

Priorities for research on agricultural chemicals have followed the growth in the markets. Following the initial research on and sales of DDT a number of chemical companies began to invest in insecticide research. As the growth of insecticide markets slowed and the demand for herbicides increased, companies moved into herbicide research. Now a number of companies are increasing their investments in fungicides. They have moved to increase their research on

Table 7. Pesticide Export in millions U.S. $

| | 1960 | 1965 | 1970 | 1975 | 1978 | 1979 | 1980 | 1981 |
|---|---|---|---|---|---|---|---|---|
| Belgium | 2 | 7 | 18 | 53 | 152 | 235 | 384 | 264 |
| France | 15 | 24 | 43 | 169 | 278 | 395 | 419 | 404 |
| W. Germany | 43 | 87 | 148 | 466 | 661 | 747 | 795 | 754 |
| Italy | 4 | 7 | 16 | 71 | 90 | 89 | 121 | 110 |
| Netherlands | 14 | 21 | 33 | 99 | 151 | 142 | 205 | 151 |
| Switzerland | 18 | 22 | 78 | 209 | 273 | 274 | 317 | 305 |
| UK | 22 | 33 | 80 | 192 | 333 | 424 | 491 | 511 |
| USA | 102 | 53 | 102 | 355 | 448 | 519 | 554 | 547 |
| Brazil | - | - | 0 | 6 | 10 | 22 | 27 | 32 |
| India | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 2 |
| Pakistan | - | - | 0 | 0 | 5 | 3 | 4 | 4 |
| Japan | 2 | 13 | 18 | 70 | 100 | 120 | 141 | 149 |
| All DC's | - | - | - | 1909 | 2758 | 3266 | 3778 | 3523 |
| All LDC's | - | - | - | 78 | 141 | 159 | 233 | 241 |
| Total | 237 | 324 | 607 | 1987 | 2899 | 3425 | 4011 | 3764 |

Source: FAO Trade Yearbooks.

Table 8. **Pesticide Import in million U.S. $**

| | 1960 | 1965 | 1970 | 1975 | 1978 | 1979 | 1980 | 1981 |
|---|---|---|---|---|---|---|---|---|
| Belgium | 2 | 5 | 14 | 50 | 140 | 155 | 144 | 116 |
| France | 4 | 11 | 47 | 156 | 262 | 336 | 407 | 424 |
| W. Germany | 2 | 7 | 20 | 71 | 143 | 185 | 223 | 185 |
| Italy | 1 | 8 | 25 | 54 | 86 | 133 | 158 | 116 |
| Netherlands | 3 | 6 | 20 | 67 | 118 | 109 | 118 | 106 |
| Switzerland | 1 | 4 | 7 | 19 | 35 | 42 | 41 | 39 |
| UK | 4 | 4 | 14 | 51 | 135 | 250 | 244 | 188 |
| USA | - | 3 | 11 | 101 | 165 | 194 | 266 | 283 |
| Brazil | 10 | 9 | 19 | 101 | 125 | 53 | 31 | 8 |
| Argentina | 2 | 5 | 6 | 15 | 19 | 36 | 44 | 47 |
| Bangladesh | - | - | - | 7 | 5 | 6 | 6 | 9 |
| India | 1 | 4 | 7 | 27 | 21 | 23 | 25 | 27 |
| Pakistan | 0 | 7 | 7 | 26 | 25 | 19 | 20 | 12 |
| Thailand | 1 | 4 | 8 | 16 | 45 | 57 | 66 | 71 |
| Indonesia | - | 1 | 12 | 41 | 29 | 27 | 26 | 25 |
| Philippines | - | 2 | 5 | 11 | 14 | 16 | 12 | 15 |
| Japan | 7 | 0 | 16 | 43 | 59 | 73 | 92 | 77 |
| All DC | - | - | - | 1300 | 1979 | 2461 | 2938 | 2735 |
| All LDC's | - | - | - | 920 | 1173 | 1225 | 1292 | 1406 |
| Total | 198 | 341 | 657 | 2220 | 3152 | 3686 | 4230 | 4141 |

Source: FAO Trade Yearbooks.

foreign problems as growth in the U.S. market slowed. The private sector does little work on small regions or commodities or IPM systems research.

Issues of market structure

The pesticide industry in the U.S. can be divided into four levels: (1) the producers of active ingredients; (2) the formulators who mix the materials with the active pesticide chemical to produce a commercial product; (3) the distributors and (4) the retailers. There is little concentration in the distribution and retail sale of pesticides. The Federal Trade Commission judged concentration at the formulation level to be "fairly low" at the second and third levels but "moderately high" at the first level. The 4 and 8 firm concentration ratios among producers of active ingredients were 57 and 79 percent (Leibenluft 1981:50). There is greater concentration in individual markets like corn herbicides, but the share of any one firm tends to fluctuate considerably over time.

The amount spent on agricultural research increases with firm size. Annual surveys of the U.S. industry by the National Agricultural Chemicals Association indicate that the research intensity of the smaller firms in the industry is higher than the medium and large size firms (Table 6).

The high research intensity of the industry can be explained by a combination of factors. Oligopoly power and patent protection allow firms to set prices high enough to profit from research. However, rapid obsolescence of products due to resistant pests and new products by other firms force companies to invest in research to retain or increase their market shares. Demand is highly price inelastic and has been shifting outward rapidly from the 1940s until the early 1980s. As a result, firms can capture a major share of the benefits from innovation because raising the price of the new chemical will not necessarily lead to a reduction in quantity demanded.

Relationship between industry, universities and USDA

The process of developing a new plant protection technique usually requires the interaction of both the public and private sector. Private sector research by chemical companies has concentrated almost entirely on chemical control of pests while private research by seed companies has attempted to breed in biological resistance to major pests. Until very recently almost all of the work on biological controls of pests has been in the public sector. Most of the work on integrated pest management has also been in the public sector. In the U.S. the public sector does most of the research on basic biology of the plants and pests and the way chemicals affect plants.

The research and development of new pesticides is primarily done in the private sector in the U.S. but the public sector still plays an important role. The public sector plays an important role in the bioefficacy research although many of the largest companies now do most of their own testing for effectiveness. State experiment stations play an important role finding new uses for pesticides which are already registered. Finally for minor uses of pesticides and drugs, the State Experiment Stations have a cooperative project (IR-4) which helps generate the data that are necessary to register biological control agents for the first time or obtain labels for new uses of a pesticide that has already been registered.

Technology transfer

The U.S. exports a substantial amount of pesticide (Table 7) but contrary to the seed situation, it does not dominate world markets. Asia is a relatively small market for pesticides (Table 8), but it is growing more rapidly than most other markets.

The companies we interviewed had varied opinions about how fast they would transfer new chemicals to other countries. There were three important issues that companies brought up in interviews. The first issue is the size of the market they can expect for the chemical. This is determined by the size of the market for pesticides, the availability of competing products, their prediction of future government policies and the ability of other firms to imitate and sell the new chemical. This last factor is affected by the capacity of the local chemical industry and by the patent protection provided by the government. The second issue is the cost of transferring the technology - this may include the cost of establishing a distribution network, advertizing, and the cost of setting up a production plant or modifying an old plant. The third issue is the production infrastructure. The agricultural chemical industry needs other industries to produce intermediate products like chemicals and machinery. If these other industries are not available, it is less likely to transfer production facilities for a new chemical.

There is little agreement among firms about how fast technology would be transferred to some developing countries. Argentina has a patent system but has not signed the Paris convention on patents so one company, which is very concerned about patent rights, stated its reluctance to introduce its newest chemicals there. Most other companies did not appear to have particular concerns about Argentina. Thailand is another country about which chemical companies have mixed feelings. There was no patent system until about four years ago. No patents have been challenged in the courts yet, so no one knows whether the patent system will work or not. One major American company will not expand in Thailand or introduce new products there because it feels that it recently had a new product stolen by a local competitor. Other companies are attracted to Thailand because the registration requirements are almost nonexistant so companies can introduce a new product very quickly there.

Chemical companies in the Third World

The market structure of the pesticide industry varies considerably among the countries of Asia. With the exception of India a common characteristic is that there are many formulators and few producers of active ingredients. India in contrast, produced 95 percent of its active ingredients. Government-owned companies are major formulators and producers of active ingredients in South Asia and Indonesia. Multinational companies play an important role in all countries. In the Philippines and Thailand most of the formulators are subsidiaries of multinational corporations or joint ventures between multinational corporations and local companies. In Indonesia multinationals and government owned corporations produce most pesticides. In India multinational companies and large scale units produce 30 percent of pesticide production while the other 70 percent is produced by the small scale formulators (APO 1983: 94).

The pesticide industry as a whole in most of these countries appears to be quite competitive. For example 21 major companies operate in the Philippines and there are many smaller formulators. In India in 1980/81 22 major companies were producing key insecticides and in 1977 there were 4,351 formulators. (APO 1983: 95). As in U.S. industry, one or two firms may dominate the market for a particular crop. In addition there is a lot of government intervention in determining prices, licensing capacity, patents and other areas which prevent competition or channel it into certain areas.

In Asia there are examples of the interaction between the public sector research and private companies. In the Philippines an example of the interaction is seed treatment for downy mildew of maize. The company knew that the chemical worked for similar diseases elsewhere so they informed scientists at the University of the Philippines at Los Banos. The scientists tried the chemical on a number of crops and found that it was very effective in controlling downy mildew when used to treat maize seed.

A lot of bioefficacy tests are done by the public sector: sometimes a government scientist is financed directly by the company; sometimes the company finances general pesticide research; and sometimes this testing is financed by the public sector.

The main factors that have led to the increase in technology transfer and research in Asia are the slow growth of the U.S. and European markets and the rapid growth of Asian markets for pesticides. Another positive factor in recent years has been the end of the government monopoly in pesticide distribution in Pakistan and Bangladesh. If this policy lasts for several years, there will be more incentive for companies to invest in research. There have been several factors that have reduced companies' enthusiasm for Asia in recent years. The first is the weakening of patents in India and the lack of enforcement of patents coupled with the growth of the local chemical industry in Thailand. The second is the Bhopal disaster. Companies are clearly waiting to see what will happen to Union Carbide.

## Development of the U.S. Poultry Breeding Industry

This history of research in this industry is quite similar to the history of research in the seed industry. There was little research on poultry by the private sector until the idea of developing hybrid birds was introduced by Pioneer and DeKalb, the leaders of corn seed breeding. This enabled breeders to collect a larger share of the benefits from their research because, like hybrid corn, farmers came back to them regularly for new chicks and other companies could not easily duplicate the characteristics of their hybrids. They started developing inbred lines and selling them in the 1930s and 1940s. The size of private sector research on breeding seems to have followed the increase in sales upward.

At present a fairly small number of private companies produce all the new varieties of broilers and layers in the U.S. USDA and the Land Grant universities do not produce new varieties of poultry although some of the universities did sell breeding stock before 1950. Between 40 and 50 companies breed poultry. Most of them are located in the U.S. The world market for layers is dominated by three firms - Shaver, Hyline and DeKalb - which account for 65 percent of the market. In the broiler market about 90 percent is controlled Hubbard, Arbor Acres, Eurobird, Cobb and Ross (Agribusiness Associates, 1981).

Most of the companies in this industry are small firms that specialize in breeding poultry. Only a few of them are owned by the large integrated poultry production operations which dominate the commercial poultry industry. A few of these companies have been purchased by pharmaceutical companies - Hubbard by Merck & Co., and Cobb by Upjohn. Eurobird is owned by British Petroleum. The pharmaceutical firms thought there would be synergy in the distribution system rather than in research. There is some debate about the trend in ties with pharmaceutical companies. Agribusiness Associates (1981) do not believe that there is a strong trend in this direction. In fact they mentioned that at least one pharmaceutical company had sold its interests in poultry breeding and others were trying to sell. They felt that the market was small and the industry so competitive that no one was making big profits.

Agribusiness Associates say that much of the competition in this industry is due to technology and that the industry has a high research to sales ratio. Unlike the other industries that we are concentrating on we do not yet have data on the expenditure on research by the breeder industry.

The relationship between public and private sector research differs considerably from the seed industry. In poultry, the public sector does not provide breeding stock and does not seem to do work in population improvement.

Instead it has been concerned with improving breeding methods and basic research in poultry genetics to encourage more effective breeding and better breeds. It also plays a major role in poultry management.

It appears that the institutional changes which are lumped together as integration were as important or more important in increasing productivity than breeding and pharmaceuticals. There seems to have been a process of interaction between technical changes and institutional changes. Integration clearly was associated with technical change in feeding and disease control which allowed producers to raise chickens and turkeys in large confined units at any time of the year. Large confinement units also led breeders to produce new types of birds which would produce more efficiently. In addition new product development and market integration have increased the demand for poultry production.

Technology transfer

The transfer of poultry technology has been primarily through the private sector. The pattern of technology transfer by the private sector is similar to that discussed in the literature review and observed in the seed industry. These companies established subsidiaries in the large, well developed markets of Europe in the 1950s. They then moved to Japan and Latin America in the 1960s. Finally, they established themselves in the Middle East and other developing countries in the 1970s and 1980s. Initially (1950-65) the companies expanded by investing in reproduction facilities. Since 1965 they have been divesting themselves of these subsidiaries because they were losing money because of long distance management problems.

Now most companies operate internationally through franchise arrangements. Technology is transferred by shipping parent or grandparent stock to the local franchise holder who multiplies them once or twice and sells them to the commercial growers. The breeding and screening of hybrids is done almost entirely in the U.S., Canada or Europe. The companies said there was no need to do research elsewhere because it was possible to replicate the conditions the birds might face here.

These companies appear to provide management technology along with the chicks. They regularly visit their franchise holders to check on disease problems and other management problems and provide them with the latest advice on how to deal with these problems. In the initial phase of commercial poultry development in many countries the breeding companies led the way in introducing commercial technology.

Poultry research in the Third World

Private companies which provide the parent stock to commercial poultry operations in Asia are almost all either subsidiaries of or joint ventures with multinationals. In most Asian countries this industry seems to be competitive, but we will have to check this statement on our field trips to Asia.

Private companies in developing countries do not seem to be involved in poultry breeding whether they are local companies or subsidiaries. There has probably been improvement in management techniques and construction of buildings which is done locally but not reported as R&D.

## V. The Impact of Private Sector Technology Transfer and Research on Agricultural Production

The major source of agricultural growth in the last two decades in Asia has been the seed and fertilizer technology associated with the Green Revolution. This has been condemned by some scholars as a conspiracy by multinational companies from developed countries to force subsistance peasants to buy manufactured inputs like fertilizer and pesticides (George, 1977). In contrast defenders of the Green Revolution have tended to focus almost entirely on the role of the International Agricultural Research Centers and government research and extension systems. There has been very little if any discussion of the role of private agribusiness.

The actual role of agribusiness is somewhere in between the extreme positions. There is no evidence of a conscious conspiracy by multinationals who supply agricultural inputs, the IARCs and Asia government research systems to develop technologies to make Asian farmers dependent on cash inputs. Rather the evidence suggests that scientists were responding to charges in the input prices and technical breakthrough in breeding wheat and rice (Hayami and Ruttan).

Private agribusiness did play an important role in transferring new varieties of rice and wheat plus the package of practices including fertilizer and pesticides from the government research organizations and IARCs to farmers. The activities of ESSO in Pakistan is a good example of this role. In the late 1960s ESSO built a fertilizer plant in Pakistan. To increase the demand for fertilizer they worked with government scientists to popularize the modern varieties of wheat and rice. ESSO set up demonstration plots of the new varieties using the package of practices recommended by the government which included fertilizer. They provided scientists with transportation to set up trials and observe ESSO's trials. The government developed fertilizer recommendations for the major regions of the country. There were no local recommen- dations. ESSO decided to set up their own soil testing laboratory and deve: recommendations for farmers who wanted them. This service allowed farmers use fertilizer more efficiently. It probably reduced the fertilizer use foı few large farmers who used too much but also encourage many more medium and small size farmers to use fertilizer because they got higher payoffs for the investment in fertilizer.

ESSO seems to have played a similar role in the Philippines. However, t they did not make enough money so they sold the local company to Planter's Products. They have continued to play an important role in technology trans They conduct thousands of demonstrations each year of improved crop varietie and production techniques. Shell Chemica. s Co. (Philippines) officials were also major supporters of Green Revolution technology. They actively participated in planning and implementing a pilot project using modern rice varieties. Then they lobbied for the adoption of the Masagana 99 accelerate rice production program. Shell received a presidential award in recognition their role in helping develop the Masagana 99 program.

In India the Indian Fertilizer Producers Association had a large fertili demonstration program throughout the country. The Indian Pesticides Asociati had a similar program.

The Indonesian government tried to incorporate the fertilizer and pestic companies into the government development program. In 1968 the government invited these companies to promote inputs and management advice directly to farmers in certain areas. However, this program (BIMAS GOTONG ROYONG) lasted only four seasons as a country-wide program although some companies continued participate for a longer period. (Timmer, 1975).

Asian governments played a major role in popularizing these inputs. The three major policies were: government subsidies of inputs themselves, indirect subsidies through subsidized credit, and the provision of information about these technologies through government extension services. These policies did not always strengthen private agribusiness since government corporations frequently manufactured and distributed these commodities.

AID also played a role in popularizing these chemicals by providing them as commodity AID in the 1960s and 1970s. In 1975 AID stopped providing money to buy pesticides of any sort, but fertilizer aid has continued to many of the poorer Asian countries.

It is not possible to separate how much of the benefits from the Green Revolution were due to private and public sector activities. The private and public sector are simply too interlinked.

Poultry is the other industry where direct transfer of technology has been extremely important. The commercial poultry industry is now growing rapidly in India, Pakistan, the Philippines, Thailand and Indonesia. The hybrids birds which are the basis of this growth were all developed in North America or Europe. These birds are sold to breeders in LDCs as grandparent or parent stock. Since the public sector has had relatively little impact, it should be possible to measure the impact of private sector technology transfer in the near future.

The impact of local private sector research and innovative activity so far has been limited. The most important impact may have been on farm machinery where innovations have reduced the financial cost of mechanization, have saved foreign exchange by increasing local content, and have saved labor and animal power. The second most important impact may have been on tobacco production. Tobacco producers have identified the best Virginia tobacco varieties and have developed cultural practices which reduced the cost of producing tobacco in Pakistan, Bangladesh, Thailand and India. Research by private companies has reduced the cost of production in some plantation crops by fine tuning the results of research from collective research programs like the Rubber Research Institute of Malaysia. Research has recently increased the yield of corn in the Philippines and corn, sorghum and millet in India. Local pesticide research accelerated the adoption of agricultural chemicals, developed some new combinations of chemicals, increased the safety of these chemicals but since it is quite recent most of the impact pesticides has been due to the direct transfer of technology. In sum, private sector research has increased the rate of adoption and widened the geographic spread of new technology developed elsewhere.

The industries that will be the major sources of new technology in the future will probably be the major seed, chemical and pharmaceutical multinationals and to a lessor extent some of the smaller biotechnology firms. Hybrid rice developed by the private sector based on Chinese and IRRI research may become an important source of growth in the future. The major source of increased yields and decreased costs in the future in the developed countries is expected to be the new biotechnology. The firms that are making the major investments in this field at the moment are the large chemical and pharmaceutical firms plus a number of new biotechnology firms and some independent seed companies.

New biotechnology will probably not have a major impact on agriculture in Asia until the 21st century (Barton, 1984). However, some of the new biotechnology is about to go into production in Malaysia. Oilpalm varieties developed using tissue culture are yielding their first harvest on experiment stations. Tissue culture is being used to grow disease free potato seed in Vietnam and elsewhere in Asia. Actual genetic engineering of plants is not expected to affect American crop agriculture until the 21st century. The effect on Asian crops will come later than in the U.S. because less is known about the basic biology of major Asian crops like rice.

## VI. AID Projects to Promote Private Research and Technology Transfer

There is no one place at AID in which one can identify all of the projects that deal with agricultural technology transfer or research by private sector. This is in part due to the decentralized structure of AID and also the diverse nature of the projects which can encourage private sector research. I have identified three types of projects which encourage local research and technology transfer by the private sector: (1) projects that finance or subsidize private research and technology transfer, (2) projects which reduce the cost of research inputs or increase their efficiency, and (3) projects which support research and technology transfer indirectly by supporting the industry. I have not attempted to give a complete catalog of the projects that fit into each area but have provided examples in each area.

So far I have identified few projects that directly finance or subsidize private sector research. A Honduran project comes close. In June 1984 a USAID project in Honduras helped set up an autonomous research foundation - the Honduran Foundation for Agricultural Research (FHIA) - to do research on export crops. It took over the facilities and genetic collection of United Fruit Company's banana research program. It was hoped that it would receive funds from the private sector - both commodity organizations, national companies and multinational corporations. So far, however, all of its funds come from AID, IDRC and the Honduran government. There does seem to be the possibility of private funding in the future from the banana companies and some of the well-organized farmers organizations.

In India AID is proposing a Fund for Technology Development which will support local research and development in the private sector by promoting joint ventures between Indian and American firms. The project is supposed to provide venture capital for high technology joint ventures through the ICICI. In the

U.S. the project will also publicize the opportunities available and finance some exploratory trips by U.S. firms to India. It is hoped that the Indian companies will be able to improve their research management capability by working with U.S. firms that effectively manage research. Agriculture is one of the main areas of emphasis of this project.

Perhaps the most important investment that AID has made to the development of Asian private sector research was the investment in trained manpower. AID's investments in the agricultural universities of Asia and in the training of Asian scientists in the United States was mentioned by executives of several major U.S. corporations as AID's most important contribution to agricultural development. Preliminary discussions with Asian technicians and scientists in the private sector revealed that most of them were trained at institutions which AID helped to finance or had their training financed by AID.

Another type of assistance to research and development is support for the CGIAR institutions that provide germplasm to any institution including private companies that requests seed. This has been important in the corn seed industry and wheat in a few countries. AID also continues to support INTSOY and INTSORMIL which also assist private research through the exchange of crop materials.

AID has financed another program of the international centers that has increased the productivity of private sector innovative activity. This is the rice mechanization program at IRRI. The agricultural engineering department has developed designs for rice threshers and two wheeled tractors that were distributed to small machinery manufacturers in the Philippines, Thailand and Indonesia. These designs have given these small companies the basic machine which they can now modify to meet their conditions. Mikkelsen (1984) concluded that this research and extension activity has increased the innovative behavior of Philippino firms. Data gathered by the impact study indicate that this activity reduced the cost of these implements and their import requirements.

There are many projects that support industries which do research and thus provide incentives for companies in those industries to do research. This support may take the form of inducing changes in government policy, assisting the government to "rationalize" their regulations, subsidizing a certain industry, or providing technical assistance which helps to popularize new technology produced by industry.

AID and other donors have had programs to assist the seed industry in most Asian countries. As mentioned in the section above public sector research on hybrid crops preceded the development of private sector research in all of these countries. This research at least partially was funded by the Rockefeller Foundation, AID and other donors. In India, Korea and Turkey, AID or IBRD projects financed consultants to assist in the development of seed laws and regulations of the seed industry. In Thailand AID has built up the physical infrastructure and provided training for private seed companies. AID through OICD is also financing technical training in seed production for several people from private companies in the Third World.

The International Agricultural Research Centers have helped by providing training on seed production at CIAT and CIMMYT.

The World Bank and AID have also supported the development of government seed production facilities which sometimes compete directly with private companies. In fact most of the Bank and AID seed projects have supported government seed companies. Some type of government support for seed product may be justified in crops where there is little possibility that the private sector could make profits or where government companies may be necessary to keep the industry competitive. However, in India the National Seed Corporation and state seed corporations which the Bank has supported have probably delayed the growth of private seed companies that can not compete with the government subsidized prices.

In the past AID financed the purchase of pesticides by some Asian countries. This practice stopped in 1975 when AID agreed in a court case that it would only support integrated pest management. AID finances the Consortium for International Crop Protection (CICP) at the University of California. This consortion offers seminars on integrated pest management, pesticide management, pesticide protection, and pesticide residue analysis. It also conducts crop protection surveys, provides technical assistance and publishes a newsletter. AID finances the International Plant Protection Center at Oregon State University which does research on and provides technical assistance on weed problems in developing countries.

AID missions have played an active role in assisting the pesticide industries in a number of countries. In India AID helped organize the Pesticide Association of India. This organization attempted to regulate itself and lobby the government for certain regulations. In recent years AID has helped leverage the governments of Pakistan and Bangladesh to privatize the supply pesticides. IRRI has an active program of testing the efficacy of agricultural chemicals. IRRI's program is the basis of many government's decisions about what chemicals to buy or permit the use of.

In the agricultural machinery industry AID has financed direct intervention in the innovation process. AID has financed the IRRI outreach program on agricultural mechanization in the Philippines, Thailand, Indonesia and India. It has been particularly successful in the Philippines where IRRI/Ministry of Agriculture technical assistance has helped local manufacturers develop improved threshers and power tillers (Mikkelsen, 1984).

There are also a number of projects to promote technology transfer by the private sector. The Bureau for Private Enterprise provides grant money to the Joint Agricultural Consultative Committees (JAC Corp.) to identify potential joint ventures. JAC Corp established committees of U.S. and Third World business men in Thailand, Indonesia, Nigeria and Sri Lanka to exchange information and pursue joint ventures. The Science and Technology Bureau has a project to subsidize private U.S. firms that will link small firms in Asia with small firms in the U.S. which have the technology needed by Asian firms. Indonesia has a similar project but provides money to an Indonesian consulting firm.

Companies' Comments on AID Programs

In the seed industry companies suggested that aid agencies stop financing government seed companies that compete directly with them. Some companies also believed that AID had encouraged countries to adopt laws that made it more difficult and expensive to develop improved seed varieties.

A number of people associated with the pesticide industry felt that AID did not understand the chemical industry and were prejudiced against it. Companies complained of exaggerated reports of deaths by CICP people to justify integrated pest management. Like the seed industry they felt that some AID programs had led to registration and regulation procedures that were not appropriate or possible to carry out in developing countries. They also complained that AID officials had patronizing views towards local officials' decisions about which chemicals to use - they cited an example of AID holding up loans to Sri Lanka to try to pressure the government to stop using DDT. They realize that AID is under considerable pressure from environmentalists, but think that AID is being more cautious than it should be.

The pesticide industry saw several places where it might be possible for them to cooperate more closely with AID. They suggested that they had a common interest in developing standard regulations on factory safety, registration, regulation and pesticide use. The reasons companies wanted such regulations appears to be to (1) improve the image of the industry by controlling the "bad guys", (2) increase the cost of their competitors who do not follow U.S. environmental and safety regulations overseas, (3) eliminate the older, less profitable chlorinated hydrocarbons like DDT and BHC and in the process increase the demand for the more modern pesticides, which are safer for the environment, more effective and more profitable.

The chemical industry also suggested joint programs to educate pesticide application firms, farmers and extension workers about safe ways of using pesticides. One company also suggested a program like the IR-4 program in the U.S. In this program the USDA pays some of the costs of getting a pesticide or biological control agent registered or labeled for a specific crop if the crop is too minor for a company to profitably develop the chemical. This basically means that a government or international agency would subsidize the cost of registering a new chemical or getting labels so that it can be used on a different crop.

## REFERENCES

Agribusiness Associates, Inc. "The International Poultry Breeding Industry," draft report, July, 1981.

Asian Productivity Organization (APO). Agro-Pesticide Distribution and Use in Asian Countries, Tokyo: APO, 1983a.

Asian Productivity Organization. Farm Mechanization in Asia, Tokyo: APO, 1983b.

Barsky, Osvaldo. "Articulaciones Sociales y Cambios Tecnicos en el Agro Ecuatoriano," mimeo Quito: Faculdad Latinoamericana de Ciencias Sociales May, 1985.

Barton, John H. "The Effects of the New Biotechnology on the International Agricultural Research System," USAID Contract No. DAN-1406-C-00-4027-00, 1984.

Behrman, Jack N. and Fischer, William A. Overseas R&D Activities of Transnational Companies. Cambridge: Oelgeschlager, Guner and Hain, 1980.

Binswanger, Hans P. "The Microeconomics of Induced Technical Change," in Hans P. Binswanger and Vernon W. Ruttan (eds.), Induced Innovation: Technology, Institutions, and Development, Baltimore: Johns Hopkins University Press, 1978.

Butler, L.J. and Marion, B.W. "The Impact of Patent Protection on the U.S. Seed Industry and Public Plant Breeding," Mimeo, Madison: University of Wisconsin, 1983.

Caves, Richard E. Multinational Enterprise and Economic Analysis, Cambridge: Cambridge University Press, 1982.

Davidson, W.H. "The Location of Foreign Direct Investment Activity: Country Characteristics and Experience Effects," Journal of International Business Studies, 11 (Fall) 1980.

George, Susan. How the Other Half Dies: The Real Reasons for World Hunger, Montclair, NJ: Allenheld, Osmun & Co., 1977.

Ghatak, S., Technology Transfer to Developing Countries: The Case of the Fertilizer Industry, Contemporary Studies in Economic and Financial Analysis, Vol. 27, 1981.

Griliches, Zvi (ed.). R&D, Patents, and Productivity, Chicago: University of Chicago Press, 1984.

India, Research and Development Statistics, 1978-79, New Delhi: Department of Science and Technology, 1979.

Jacobs, Eduardo. "El Desarrollo de la Industria de Semillas: Reflexiones a Partir de los casos de Argentina y Brasil," Mimeo, Buenos Aires: CISEA 1985.

Jacobs, E. and Edith S. deObschatke. "Ciclos Technologicos en la Region Pampeana Argentina y el Desarrollo del Sector Privado," Mimeo, Buenos Aires: CISEA, 1985.

Kalton, R.R. and Richardson, P. "Resources in Private Plant Breeding," Mimeo, Land O'Lakes Research Farm, 1983.

Kamien, Morton, I. and Schwartz, Nancy L. Market Structure and Innovation, Cambridge: Cambridge University Press, 1982.

Leibenluft, Robert F. Competition in Farm Inputs: An Examination of Four Industries: Policy Planning Issues Paper, Washington: Federal Trade Commission, Feb. 1981.

Mansfield, Edwin. "R&D and Innovation: Some Empirical Findings," in R&D, Patents, and Productivity, Zvi Griliches (ed.), Chicago: University of Chicago Press, 1984.

Mansfield, Edwin. The Economics of Technological Change, New York: Norton, 1968.

Mansfield, Edwin et. al. Technology Transfer, Productivity, and Economic Policy, New York: Norton, 1982.

Mikkelsen, Kent W. "Inventive Activity in Philippine Industry," Ph.D. Thesis, Economics Department, Yale University, 1984.

NACA (National Agricultural Chemicals Association). "Summary of the 1983 Industry Profile Study," Mimeo, Washington: NACA, 1984.

Nankani, G.T. The Intercountry Distribution of Direct Foreign Investment in Manufacturing, New York: Garland, 1979.

Nelson, Richard R. (ed.). Government and Technical Progress: A Cross-Country Analysis, New York: Pergamon Press, 1982.

Pineiro, Martin. "The Development of the Private Sector in Agricultural Research: Implications for Public Research Institutions," mimeo, Buenos Aires: CISEA, 1985.

Pliska, George C. "The Ag Chemical Industry: Complex, Costly and Exciting!" Farm Chemicals, September 1983.

Scherer, Frederic M. "Using Linked Patent and R&D Data to Measure Interindustry Technology Flows," in R&D, Patents, and Productivity, Zvi Griliches (ed.), Chicago: University of Chicago Press, 1984.

Stobaugh, Robert and Wells, Louis T. Technology Crossing Borders: The Choice, Transfer, and Management of International Technology Flows, Boston: Harvard Business School Press, 1984.

Stoneman, Paul. The Economics of Technological Change, Oxford: Oxford University Press, 1983.

Timmer, C. Peter. "The Political Economy of Rice in Asia: Indonesia," Food Research Institute Studies 14(3), 1975.

USDA,FATUS. Annual Statistical Reports, 1983.