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The Role of the Private Sector in Transferring Hybrid Corn Technology

by

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1 Introduction

It is widely accepted that new technology is an important source of agricultural growth. Developing countries have tried a variety of policies to accelerate the development and diffusion of new technology. These policies include: (1) government investment in agricultural research and extension, (2) tax breaks and other incentives to private companies that conduct agricultural research, and (3) incentives to transfer new technology developed outside the country. At the same time, many countries have other policies that reduce the incentive of private companies to do research or transfer technology. These include restrictions on importing technology and importing research inputs, restrictions on which companies are allowed to do research, and regulations that reduce the profitability of innovation.

The opposite side of this issue is the U.S. farmers' complaint that multinational companies are transferring U.S. technology to other nations. Some farmers and their representatives argue that this transfer of technology hurts American farmers by increasing the productivity of our competitors and reducing the amount of U.S. grain demanded by importing nations. There are reports of attempts by U.S. farmers to restrict the outflow of technology by restricting seed imports.

At present, the debate about these issues is hampered by the absence of empirical studies on the importance of these flows of technology or the impact of policies on these technology transfers. In practical terms, it is not clear how much technology can be transferred directly and how much has to be substantially modified before it can be used in a new country. Without such information, it is impossible to determine how important

policies which impede the flow of material technology like seeds or chemicals will be or whether foreign research will make three technologies available anyway.

In this paper, we have attempted to measure the impact of public sector research, the transfer of technology embodied in a product, and private sector research by multinationals on one major crop - corn. The results indicate that technology transfer through trade and private sector research by multinational seed companies play an important role in increasing agricultural productivity.

2 Technology Transfer and Government Policy

There are a number of ways in which a country can improve the supply of new technology for farmers. In the corn crop, there is evidence that four sources of new technology have been important: (1) imported technology in the form of varieties or hybrid seed; (2) local research and seed production by multinational companies; (3) research and seed production by local companies: (4) research and seed production by local government sometimes with the assistance of international organizations like CIMMYT or the Rockefeller Foundation.

Private sales of hybrid corn seeds and research by the private sector may also be important sources of new technology. The U.S. seed industry has been in the export business for a long time. Table 1 shows the quantity and value of exports of different kind of seeds since 1950. Grain seeds have been the major seed exports since 1970. Figure 1 shows growth of U.S. exports of hybrid corn seed. The deflated values of these exports show an important increase since the mid-1970's.

The direction of corn seed exports and its variation over time is shown in Table 2. Most of the exports go to Europe and Canada. These exports have been a very important source of new technology for a number of countries.

Table 1: U.S. Seed Exports by Type of Seed. 1950-1984.

Fiscal Year			Forage	Vegetables	Grain	Others	Total
			(Quantity: MT; Value: $1000)				
Avg.	1950-1954	(Q)	10,488	1,670	17,131	84	26,273
		(TV)	6,557	2,466	1,790	394	11,207
Avg.	1955-1959	(Q)	18,597	1,987	16,008	108	36,701
		(TV)	10,432	3,345	3,012	571	17,360
	1960	(Q)	28,630	2,107	16,461	148	47,341
		(TV)	12,750	4,244	2,815	728	20,537
Avg.	1960-1964	(Q)	26,928	2,675	17,131	151	46,886
		(TV)	13,571	5,302	3,299	781	22,953
	1965	()	28,734	2,865	1,845	2,963	49,408
		(TV)	15,569	6,094	3,531	2,557	27,856
	1970	(Q)	32,432	4,882	51,360	17,626	106,301
		(TV)	21,814	11,666	13,669	6,814	53,963
	1975	(Q)	36,033	6,359	37,429	19,965	99,787
		(TV)	43,838	30,045	22,246	16,886	113,116
	1980	(Q)	48,795	38,411	80,260	32,295	199,762
		(TV)	74,866	81,277	58,507	20,453	235,102
	1984	(Q)	92,614	17,110	217,642	35,226	362,592
		(TV)	73,144	99,499	146,718	46,280	365,641

Source: USDA Foreign Agricultural Reports.

Figure 1: Major Grain Seeds Export Growth.

Table 2: U.S. Seed Exports by Region, 1967-1985.

Country	1967	1970	1975	1980	1985
	Calendar Years, Quantity in Metric Tons				
Canada	2,380	4,661	12,987	4,460	1,920
Mexico	986	2,846	3,929	1,652	2,446
C&S America	552	1,255	1,225	1,213	1,311
EC	4,722	5,049	7,818	14,494	21,933
Asia	219	537	860	2,947	1,959
World Total	9,234	15,114	27,185	26,465	37,964

Source: U.S.D.A. Foreign Agricultural Reports.

Table 3 shows the percentage of total corn area and hybrid area under U.S. hybrids, for selected corn producing countries of the world, for 1985.

The range is considerable. Greece and Italy import about half of their hybrid corn seed from the U.S. The rest of thes countries analyzed later in this study have less than one percent of the corn area under U.S. seed. They import very little U.S. seed with respect to their total area under corn.

Scientific crop breeding by the private sector started in the U.S. in the 1930's and 1940's with the development and spread of hybrid corn. Hybrid corn sales and research by U.S. companies spread to Europe in the late 1940's and early 1950's. Private U.S. companies corn research in Argentina also started in the late 1940's and in Brazil in the early 1960's. Private research by multinationals in Asia started in the 1950's in the Philippines and 1960 in India. However, these early research efforts in Asia were discontinued in the mid-1960's, and it is not until about 1970 that sustained private corn research programs in Asia were started.

Companies expanded into Africa starting with South Africa in around 1960; Egypt in about 1980; and the Ivory Coast, Kenya and Zimbabwe in the last three years.

At present, multinationals are playing an important role in testing, breeding and transferring corn technology around the world. Major companies like Pioneer or Cargill are testing hybrids in 90 to 100 countries. They have experiment stations in 15 to 20 countries. These experiment stations tend to be concentrated in Europe and Argentina. In many countries, they developed the first private sector corn breeding programs. Their impact appears to have been quite important in several countries. For ex-

Table 3: Percent Total Corn Area, Planted and Percent of Hybrid Corn Area Planted With Seeds Imported From U.S.

Country	Percent Total Area	Percent Hybrid Area
Greece	50	50
Italy	46	46
Chile	26	39
Austria	11	11
Spain	8	7
Canada	8	8
Hungary	6	6
Mexico	5	100
France	3	3
Turkey	3	8
Germany	2.5	2.5
Egypt	2	22
Portugal	1.5	10

Column 1 was calculated using a planting rate of 17 kg/ha for ldos and 22 kg/ha for dcs, on the amount of U.S. corn seed exports. Column 2 was calculated as a percentage of the hectares that could be planted with U.S. seed - at the above rates - on the total area under hybrid corn.

ample, about half of the corn acreage in France is under hybrids of one American company and 87 percent of the hybrid corn in Argentina is from multinational seed companies (Obschatko, Pineiro and Jacobs, 1986).

Research by local companies has been an important source of technology in several countries. European seed companies have been important in producing hybrid corn and varieties of other crops. In Zimbabwe, a local company started to produce hybrid corn in the 1940's. It now produces 100 percent of the improved corn in that country and is selling corn seed to neighboring countries. In Brazil, a local company started in the early 1960's is now producing 39 percent of the country's hybrid corn seed and three other local companies produce another 12 percent (Obschatko, Pineiro and Jacobs, 1986). In India, a company founded in the mid-1960's is now producing about a quarter of the hybrid corn seed.

Public sector research is an important source of improved corn varieties in many countries. In many others, public sector research provided germplasm and the breeding techniques that were the basis of private sector breed programs. The importance of public sector research was nevertheless subject to debate particularly in the early years after World War II.

In many of these countries, U.S. based multinationals started the first private sector corn breeding programs. The companies report their operations in Europe and South America have been profitable and so there is presumption that their research activitites have paid off with seeds that are more profitable to local farmers.

The development literature has gone through a transformation in the importance it gives to technology transfer versus local research. During the 1940's and 1950's, people writing about development assumed that the

transfer of technology was a relatively easy and costless process (Moseman, 1970). This assumption was based in part on the experience on transferring hybrid corn from the U.S. to Europe after World War II. In agriculture, this resulted in policies with an extension bias. Governments and donors invested in public extension systems but not in public research because they assumed technology was available locally or could be easily transferred.

The failure of these policies to bring rapid agricultural growth and the research of Hayami and Ruttan, Evenson and Binswanger and others pointed out the importance of local research in adapting technology to local conditions. These studies argued that governments should invest in agricultural research. A large literature has grown up which shows very high rates of return to investments in agricultural research in developed and developing countries (Ruttan, 1982). Evenson and Kislev attempted to estimate the impact of government research on wheat and corn yields in the period 1948 to 1968 in 64 and 49 countries, respectively. They found that government research by other countries in similar agroclimatic regions was an important factor in explaining yields. In addition, they found that there was no impact of regional research on yields unless there was some local research on the commodity. This supports the idea that agricultural technology cannot be readily transferred wihtout local research (Evenson and Kislev, 1975).

The studies by Harvey and Timothy, 1986, trace the spread of CIMMYT genetic material in considerable detail. Recent work by Evenson (1985) has shown that the national research programs in collaboration with CIMMYT have had a significant impact on corn yields in the Third World.

Despite some evidence that all of these ways of transferring and de-

veloping technology can be important sources of growth. there has been considerable debate about whether governments should encourage the supply of technology by some of these means. For example. debate is quite heated in some countries about the proper role of the private sector in research and technology transfer. Most countries want to build their own technological capacity but are not sure about the best mix of public and private research, the role of import barriers or the barriers to investments by foreign companies. This lack of concensus is reflected in the variety of laws on seed imports and private research. Commercial seed imports are effectively prohibited in India, while in Thailand, there are very few policy barriers to imports. Until recently, private companies were prohibited from doing maize research in Pakistan while in India and the Philippines, tax incentives were provided to companies that do research. Until last year, subsidiaries of multinationals were not allowed to operate in the seed industry in India unless their equity is under 40 percent. In Argentina and the Philippines, multinationals have been encouraged to participate in R&D and seed sales.

As mentioned above, the importance of public sector research has been debated in the past and continues to be debated at present. Many government officials in developing countries are not convinced that their research program can produce much technology which will have high economic payoffs. In developed countries, some farmers argue that productivity increases due to public research have hurt them while large seed companies argue that public research should be reduced so that it does not compete against private companies.

If governments are going to make better decisions about which policies

to choose, they must have more information on the costs and benefits of such policies. To estimate these costs and benefits requires information on: (1) the marginal value product (MVP) of seed imports, the MVP of R&D by local and foreign companies, and the MVP of public research; (2) the relationship between government policies and the amount of imports and/or amount of private R&D; and (3) the financial costs of implementing government policies. With this information, for example, one could estimate the costs and benefits of prohibiting seed imports as net benefits from inducing a local seed industry minus the foregone income to farmers who were prohibited from using imported seed. The net benefits from local seed would require an estimate of how much more rapidly the local seed industry grew than it would have in the absence of import restrictions, the technical superiority of local vs. imported seeds and the differences in price between local and imported seeds. The foregone income of farmers would come from estimates of the value of imported seed. One would also have to subtract the cost of enforcing the ban on corn seed imports.

The next section of this paper contains a method for estimating the benefits (or costs) of public research and other policies that encourage (or restrict) seed imports and private research. It does not provide sufficient information for a complete cost benefit analysis because it provides information only on number (1) above not (2) or (3). It is, however, a necessary step in the process of estimating costs and benefits and does add to the very limited number of studies in this area.

3 Model and Empirical Results

To test the relative importance of research and technology transfer on crop productivity, we have developed the following model. We used a partial Cobb-Douglas production function (F) of the following form:

$$(YIELD)_{it} = F[(HSI)^{b_1} (FERT)^{b_2} (EDUC)^{b_3} (PUBR)^{b_4} (PRIVR)^{b_5} (ACD)^{b_6}]_{it}$$

where: i-1...50 countries, t=1... time periods from 1961 to 1984.[1] Table 4 describes the variables utilized in this study and the sources of data.

The model is a partial one since not all possible variables explaining yield are included. As an initial attempt at assessing the costs and benefits of importing technology, encouraging local research or investing in public sector research, we applied this model to data on the corn crop. This crop was chosen for several reasons. First, this is an important crop world wide.

[1]COUNTRIES - A ranking by production of corn was constructed for the period 1981-1984 using the F.A.O. Production Yearbook. The first fifty countries of that list were chosen for this study. The production range was from ··· to ··· thousand metric tons. The countries are: China, Brazil, Mexico, Romania, USSR, Yugoslavia, Argentina, France, South Africa, Hungary, India, Italy, Canada, Indonesia, Thailand, Egypt, Philippines, Bulgaria, Korea DPR, Spain, Kenya, Zimbabwe, Nigeria, Greece, Tanzania, Austria, Ethiopia, Turkey, Malawi, Guatemala, Pakistan, Germany FR, Colombia, Zambia, Czechoslovakia, Afghanistan, Nepal, Zaire, Peru, Chile, Paraguay, Venezuela, Portugal, El Salvador, Viet-Nam, Bolivia, Honduras, Uganda, Cameroon and Ivory Coast. TIME PERIODS - The five periods covering from 1961 to 1984 were: (1) 1961-1965, (2) 1966-1970, (3) 1971-1975, (4) 1976-1980, (5) 1981-1984.

Table 4: Explanation of Variables and Sources of Data.

YIELD	CORN YIELD in metric tons per hectare, from FAO Production Yearbook.
HSI	HYBRID SEED IMPORTS. Metric tons of hybrid corn seed (and inbred lines) imports from the U.S. divided by corn area in country i at t. To construct this variable, the average quantity of U.S. corn seed exports per period was divided by the average corn area in each country. The seed exports information is from the U.S.D.A. Area from F.A.O. Production Yearbooks.
FERT	FERTILIZER. NPK per ha of arable land in country i at t. Since there is no information available on amount of fertilizer used in corn per country, the average total NPK consumption from F.A.O. Fertilizer Yearbooks was divided by average area of arable land in each period, in order to approximate the level of fertilizer usage in each country
EDUC	EDUCATION. Approximated by adult literacyrate in country i at period t, from UNESCO Statistical Yearbooks.
PUBR1	PUBLIC RESEARCH #1. Number of corn, sorghum and millet publications published in "Plant Breeding Abstracts". This variable was measured as a stock starting in 1948 and deflated by corn area in each country. For the first period, the total number of publications from 1948 to 1961 was used. For period (2) and (3), the number of publications up to 1968 was utilized. For period (4) up to 1975, and for period (5) from 1948 to 1979.
PUBR2	PUBLIC RESEARCH #2. A different variable estimating corn research expenditures was also constructed for the 1960's and the 1970's. Since data on corn research expenditures is not available in a per country basis, this information was estimated using the percentage number of corn publications in the total number of publications on the total agricultural research expenditures of each country. This estimation was then adjusted by area of corn in each country, in order to have inputs as well as output in a per hectare basis
PUBR3	PUBLIC RESEARCH #3. Number of inbred lines, open pollinated varieties synthetics and other breeding stocks released since 1948 divided by area of corn in period (5). From Maize Research and Breeders Manual No. X, Illinois Foundation Seeds, Inc. Dec., 1984.
PRIVR	PRIVATE SEED COMPANY RESEARCH. The impact of five major private multinational seed companies (Pioneer, Northrup-King, Dekalb, Cargill and Funk) doing corn research in each country was approximated by the number of years and number of research stations up to 1977
ACD	AGROCLIMATIC DUMMY VARIABLE. 1 for "TEMPERATE" and 0 for "TROPICAL".

Second, the United States dominates the corn seed trade and so there is data readily available on the U.S. corn seed exports to a large number of countries. Third, there is a considerable amount of corn research conducted by private companies. From interviews and annual reports, we were able to generate some rough indicators of private sector research on corn in most of those countries.

All of the variables are on a per hectare basis. The Hybrid Seed Imports variable attempts to measure the direct transfer of technology embodied in hybrid seed rather than the more direct measure of borrowing used by Evenson and Kislev - research in similar agroclimatic zones. HSI is clearly not a perfect measure since other countries export hybrid corn seed, but the U.S. is the large exporter of corn seed worldwide.

Three variables were tried to measure public sector research. The first, following Evenson and Kislev, is the number of research publications on corn in a country that are abstracted in Plant Breeding Abstracts. The second measure is calculated by mutiplying the ratio of corn publications to all commodity publications times the total research expenditure. The third measure of public research was constructed by adding all the number of corn lines released in each country since 1948. The private research variable was the most difficult to calculate. In the end, it was based on the number of research stations of the major multinational companies located in each country. This underestimates private corn research in countries where the local private research is most important and yields are highest, like Europe and Argentina.

Discussions with companies and with CIMMYT indicated that there were important differences between growing conditions in temperate and

tropical regions. We attempted to control for this factor by including variables on agroclimatic conditions on three types: the FAO Agro Ecological Zone Map, the Papadakis World Climatological Classifications, and a temperate vs. tropical dummy.

Using the property that the Cobb-Douglas function is linear in logs, the coefficients of the function are estimated using Ordinary Least Squares, under common assumptions (i.e., according with Gauss-Markov Theory, good estimates of these parameters can be obtained by OLS when the independent variables are uncorrelated with the error term, this term represents cumulative effect of all left-out variables) from the following regression:

$$\begin{aligned}[YIELD] &= CONSTANT + b_1[HSI] + b_2[FERT] + b_3[EDUC] + \\ &\quad b_4[PUBR] + b_5[PRIVR] + b_6 ACD + ERROR\ TERM\end{aligned}$$

where [ ] denotes logarithms of the variables, and the error term is assumed to be a random variable with mean 0 and variance G^2.

The following Table 5 summarizes the regression results for each time period. The dependent variable is yield, standard errors are in parentheses.

The results indicate that the climate is the most important determinant of yields in each period - corn yields are higher in temperate regions. Fertilizer use is the next most important determinant. It is statistically significant in all periods except the early 1960's. Seed imports from the U.S. are significant in the last two periods. Education had the expected sign but approached the 10 percent significance level only in the last period.

The public sector research coefficient did not have the expected sign and was not significant in any of the regressions. We tried several other measures of public sector research, but they also had statistically insignificant coefficients.

These results indicate that the private transfer of technology in form of hybrid seed was an important factor in determining corn yield per acre in lthe late 1970's and the 1980's. As Figure 1 showed before, it is not until 1975 that corn seed exports from the U.S. were consistently over 20 thousand tons.

We do not have good data for all five periods for private sector research. We suspect that the seed imports variable may actually be picking up some of the impact of local private research. For the last period we do have data on the number of experiment stations of private multinational companies in each country. This is incomplete because it does not include all multinationals and does not include local private research. It is, however, the best data available at the moment. The last column of Table 5 incudes the private sector research variable (PRIVR). Private research is significant at the five or ten period level. The coefficient on the seed import variable is reduced in size and is no longer significant. This supports the hypothesis that the seed imports variable is a proxy for private research.

Table 6 shows the results of pooling the data for the fifty countries over different periods of time. First, the whole period 1961-1984 is analyzed using the same variables as in Table 6 for the cross-section results. We did make an initial attempt to see if private research was important. In specification 3, Table 6, the private sector research variable used in Table 5 was added. It is the number of stations times the number of years between

Table 5: Cross-section Results for the (5) Time Periods.

	(1)	(2)	(3)	(4)	(5)	(5)	(5)	(5)
HSI	.015^	.019^	.005^	.029**	.031**	.030**	.015^	.016^
	(.012)	(.014)	(.014)	(.013)	(.013)	(.013)	(.014)	(.015)
FERT	.046^	.124**	.130***	.106**	.141***	.137***	.144***	.15***
	(.032)	(.049)	(.048)	(.041)	(.046)	(.046)	(.044)	(.045)
EDUC	.113^	.102^	.171^	.169^	.225^	.223^	.126^	.133^
	(.082)	(.142)	(.40)	(.127)	(.142)	(.143)	(.145)	(.146)
PUBR#1	-.008^	-.016^	-.004^	-.005^	-.009^	--	--	-.012^
	(.012)	(.016)	(.015)	(.015)	(.022)	--	--	(.021)
PUBR#3	--	--	--	--	--	-.008^	-.032^	
	--	--	--	--	--	(.040)	(.040)	
PRIVR	--	--	--	--	--	--	.117**	.107*
	--	--	--	--	--	--	(.056)	(.054)
ACD	.353***	.446***	.538***	.597***	.492***	.511***	.520***	.476***
	(.116)	(.137)	(.135)	(.130)	(.142)	(.143)	(.138)	(.138)
ADJ.R2	.44	.50	.60	.69	.65	.65	.67	.67
S.E.R.	.35	.41	.39	.38	.41	.41	.40	.40

Note: (^) not significant, (*) significant at P=0.10, (**) at P=0.05 and (***) at P=0.01. Adj.R2 is adjusted R-squared. S.E.R. is standard error of regression. Two tail "t" test with (50-p) degrees of freedom, where p is number of regressors. See appendix for regressions, correlation matrix, mean and standard deviation of each variable and residual plots.

Table 6: Pooled Estimation, 1961-1984.

HSI	.023***	.017***	.006^
	(.006)	(.006)	(.006)
FERT	.109***	.102***	.100***
	(.018)	(.018)	(.017)
EDUC	.127***	.112**	.073^
	(.049)	(.048)	(.048)
PUBR#1	-.010^	--	--
	(.006)	--	--
PUBR#3	--	.025^	.010^
	--	(.016)	(.016)
ACD	.474***	.470***	.086***
	(.059)	(.59)	(.23)
ADJ.R2	.60	.60	.62
S.E.R.	.39	.39	.38

1960 and 1977 each station was open. Thus, all the variation is between countries, it does not vary between time periods. this variable came out very significant. It also reduced the seed imports' variable in size, and imports is no longer significant. It also reduced the size of the coeffient and significance of the education and public research variables.

The results of pooling the five cross sections are quite good in the first two specifications. All of the coefficients except public research had the expected sign and are significant. When the number of lines released (PUBR#3) rather than the number of publications (PUBR#1) is used for the public research variable, the coefficient of research is positive but is still not significant.

The coefficients on the fertilizer variable and the temperate-tropcal variable are significant like they were in the cross sections. The education variable is also signifcant unlike the cross sectional results.

The regressions using the pooled data strengthen the cross sectional results that seed imports can contribute to yield increases. The size of the contribution may be biased upward because the information we have on the private research effort is not complete.

Seed imports and multinational research are the only technology transfer variables that are statistically significant in the pooled data and in some of the cross sectional data sets. Public sector research was not significant in any of the regressions. Previous research (Griliches, Evenson and Kislev, Binswanger and Ruttan) suggests that local research is necessary – particularly for a location sensitive plant like corn. The fact that a very crude measure of private research is significant and reduces the size and significance of the seed imports variable supports this position.

Seed imports and private research are closely related. Case studies from Asia and Latin America suggest two patterns. In temperate regions, companies start selling hybrids developed in the U.S. after a minimum amount of testing and then invest in research to tailor the hybrids to local conditions as their market expands. At first they import the hybrid seed from the U.S. because it is cheaper than establishing their own production and processing operation. As the market grows, companies usually set up their own operations and then import seed when it is cheaper from the U.S. In the tropics, research either by the public or private sector is required first to develop suitable hybrids then companies start selling seeds that are multiplied in subtropical parts of the U.S. and eventually in the tropical country.

The lack of significance of the public sector research variable is puzzling. In temperate climates, public sector research still appears to play an important role in improvements of corn germplasm and management practices although the private sector may now be investing more money than the public sector in corn research. In most countries in the tropics the public sector invests more than the private sector although there are some notable exceptions like Argentina and the Philippines. Public research has played a key role in increasing yields in several of these countries (Suthad, 1986). These impressions are reinforced by Evenson's studies of twenty-four developing countries which indicate that public research was important (Evenson, 1985). It may be that past studies which have not had an explicit technology transfer variable have overestimated the importance of public research. This is an issue that requires further study.

4 Some Preliminary Policy Implications

Countries that prohibit the import of corn seed are losing out on an important source of growth in corn productivity. The losers from these policies are the farmers and the companies would import seeds. Consumers of corn and cornfed livestock are also losers. Therefore, when governments evaluate policies that restrict seed imports they must add this cost into their cost benefit analysis of these policies.

There is also evidence that research by multinationals can be a source of growth. This means that policies which restrict the activities of multinational seed companies may also impose a large cost on farmers in terms of foregone productivity. This cost to farmers and consumers is rarely, if ever, calculated.

The beneficiaries of such policies are local seed companies who are protected from foreign competition and allowed to develop their own capacity to do R&D. Farmers will also benefit if the technology local firms develop is superior to or less expensive than technology produced by foreign firms. As yet, there is little empirical evidence to show the size of such benefits to farmers. We are currently conducting resesarch with which we hope to estimate the benefits to farmers and consumers of local research.

The evidence does suggest that U.S. farmers are right that private companies are transferring technology to foreign companies. However, these companies may also be transferring useful technology back to the U.S., and a larger market can support more research intheir headquarters which are usually in the U.S. In addition, policies that stop the transfer of seeds will probably not have much impact on technology transfer since it appears that

the foreign research was most important in increasing yields.

These results are very preliminary. Much more research is required before any strong conclusions can be drawn. The next step is to develop more accurate measures of some of the variables and see if the results remain the same. Then the questions of which policies will speed the development and transfer of new technologies needs to be explored. To do this, a series of fairly detailed country studies is needed. We are beginning such studies on six countries.

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