International agricultural technology transfer: Theory and application

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International agricultural technology transfer: Theory and application

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INTERNATIONAL AGRICULTURAL TECHNOLOGY TRANSFER

THEORY AND APPLICATION

by

Fengshan Cao

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STATEMENT BY AUTHOR

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ABSTRACT

The gap that exists between the technologies in developed and less developed countries leads to the possibility and necessity of agricultural technology transfer. The lower cost of transfer compared with costs of local development leads to profitable transfer for recipient country. Recipient country must perform local research to adapt the transferred technology to their local needs and to ensure that benefits are distributed in an equitable manner. Is it in the interest of the donor country to sell technology to less developed country? Conventional arguments consider only whether technology transfer to less developed country will be against the donor country's interest in agricultural product exports. It is incomplete. Economic surplus concept has been applied here to discuss both producer's and consumer's gain or lose. An empirical analysis of the U.S.-Mexico agricultural technology transfer showed that both Mexico and United States benefitted from the technology transfer.

CHAPTER 1

INTRODUCTION

Technology has been increasingly recognized as a powerful influence on the process of economic growth. Technological change is widely accepted as the basis for increased agricultural productivity. Because of the historical prominence of research and development expenditures by developed countries, a very large part of the technology used in developing countries is transferred from developed countries. Many less developed countries have gained enormously from the use of technological knowledge accumulated in the industrialized countries.

The first part of this thesis presents a review of the economics of international technology transfer. This discussion emphasizes the reasons for international technology transfer: uneven economic and technological development opens the possibility of technology transfer; the lower cost of transfer compared with costs of local developments leads to profitable transfer; and alternative transfer mechanisms exist to facilitate transfer. Although most recipient countries have benefitted from technology transfer, some countries have faced economic and social problems. The second chapter discusses some of these problems, such as the indiscriminate importation of inappropriate technology and a consequent dualistic pattern of development, and the disincentives given to local innovation that in turn engender further technological dependence.

In addition to reviewing the theoretical research on technology transfer and its influence on the recipient country, this thesis analyzes the influence of agricultural technology transfer on the donor country. Is it in the interest of the donor country to have technology transfer? Why or why not does the donor country benefit from the transfer? It seems difficult to get a unanimity of opinion on this topic. From a static (or short-run) view of world agricultural markets, in which global demand is fixed, another country's increased production must come at the expense of donor country exports. In this respect, technology transfer will hurt the donor country's export interest. But from a dynamic view, technological change in the recipient country's agriculture can lead to rising food and feed imports in future years. This effect can occur both at low levels of income, where the income elasticity of food demand is high, and at medium levels of income, where the transition from direct consumption of food grains to the indirect consumption of feed grains through demand for animal products is occurring. In the long-run, then, technology transfer may benefit donor country exports. This thesis uses applied welfare measures of consumer and producer surplus to estimate the impact of technological change. Many research efforts on this topic examine the effects of agricultural technology transfer on the donor country's producer welfare, but ignore the effects on consumer welfare. Technology transfer may bring desirable imports of farm products to the donor country. The inflow of farm products increases supply in the donor country's market and usually lowers domestic prices. Therefore, the imports benefit consumers but hurts domestic producers.

The second part of this thesis focuses on an empirical analysis of the costs and benefits of the transfer of agricultural technology from the U.S. to Northwest Mexico. Northwest Mexico has experienced substantial growth in agricultural production over the past three decades. Most of the growth resulted from the wider use of material inputs, in particular improved seeds, fertilizers, pesticides and farm machinery, which have been mainly transferred from the U.S. The development of large-scale irrigation projects further encouraged the expansion of mechanized technologies, again largely transferred from the U.S. As a donor country, has the U.S. benefitted from this activity? Direct benefits to U.S. producers come from the export of agricultural inputs, such as capital equipment, seeds, fertilizers and pesticides; and some special services such as marketing and transportation, managerial consulting, and financial services. The technological improvement in Northwest Mexican agriculture has also encouraged economy-wide growth and income effects that further increased agricultural imports. Northwest Mexico also exported winter vegetables to the U.S. The increased availability of these products affected U.S. prices. Therefore, the transfer created benefits to U.S. consumers but brought harm to U.S. vegetable producers. Producer and consumer surplus are estimated to calculate society's net gain or lose.

CHAPTER 2

INCENTIVES FOR INTERNATIONAL AGRICULTURAL TECHNOLOGY TRANSFER

Technology refers to the package of product designs, production and processing techniques, and managerial systems that are used to produce particular goods. Agricultural technology is the knowledge of how to do all those things associated with agricultural activity. Typically it includes biological, chemical and mechanical technology. Technology may be embodied in products or held in the minds of men. It may have application in new products and new services, or in lower costs per unit output.

International agricultural technology transfer takes place when technological knowledge in one country is communicated to people and used in another country. When useful or productive knowledge is widely known, it is usually freely available to any who wish to learn. But when the technology is scarce or new, technology is likely to be treated as a commodity. There are three conditions for a technology transfer to take place: decision makers in one country wish to use a particular technology; that technology is not available locally; and the decision makers believe it is cheaper to transfer the technology than to reproduce it locally.

Although there is a certain proportion of technology transfer between industrialized countries, this thesis emphasizes international agricultural technology transferred from developed countries to less developed countries. To examine the incentives of this international transfer activity, three main ideas will be discussed: uneven economic development among countries leads to technology gaps and to the possibility of international technology transfer; the importance of technical change in agricultural development and the lower costs of new technology lead to the necessity of transfer; and the availability of alternative transfer mechanisms facilitates this activity.

2.1 Uneven Economic and Technological Development

Technology transfer from another country is not necessary if all countries have the same economic and technological development level, or if the desired technology can be easily developed locally. Uneven economic development creates opportunities for technology transfer. The industrialized countries accumulated a vast stock of technical and organizational knowledge, but the internal generation of technology in many less-developed countries is minuscule because of the lack of capital and investment. This difference means that it is possible that the LDCs can access technology from advanced countries through international trade and technology transfer.

Table 2-1 provides some statistics that show the condition of uneven economic development throughout the world. Low-income countries had more than three times the population of industrialized countries in 1985, but the GNP per capita is only 2% of that in the industrialized countries--$270 versus $11,810. Low-income economies have a larger share of agriculture in GNP than industrial market economies.

The characteristics of agriculture in DCs and LDCs are also different. In developed countries, integration between agriculture and other sectors of the economy is virtually complete. Farmers are commercially oriented and technically well-informed. They have at their disposal the services of financial, marketing, advisory and research institutions, both public and private. But in LDCs, agriculture has a high degree of self-sufficiency. The main factors of production are labor and land, and few purchased inputs are employed.

Technological development is concentrated in a few developed countries. The developed countries are responsible for 97% of world research and development expenditure. The United States, the Soviet Union, Japan, the Federal Republic of Germany, France, and the U.K. employ nearly 70%of the world's research and development manpower and spend nearly 85% of research and development funds. These countries' national

Table 2-1 Basic Indicators of Economy Development (1985)

	Population (millions)	GNP Per Capita (dollars)	Share of Agriculture in GNP	Research & Development Expenditure as a Percent of GNP
Low-income Economy	2439.4	270	32	NA
China & India	1805.5	290	31	NA
Other Low-income	633.9	200	36	NA
Middle-income Economy	1242.1	1290	14	NA
High-income Oil Exporter	18.4	9800	2	NA
Industrial Market Economy	737.3	11810	3	NA
United Kingdom	56.5	8460	2	2.42
France	55.2	9540	4	2.31
Germany, Fed. Rep.	61.0	10940	2	2.67
Japan	120.8	11300	3	2.77
Canada	25.4	13680	3	NA
United States	239.3	16690	2	2.69

* Source: The World Bank: " World Development Report 1987 "
Science & Engineering Indicators 1987

** NA= Not available

expenditures on research and development as a percentage of gross national product(GNP) are shown in Table 2-2. In nearly all of these nations, research and development spending has been growing faster than GNP.

Although some developing countries are beginning to promote local technological development, they remain dependent on the developed countries for most of their technology. A study by the Organization for Economic Co-operation and Development identified 110 significant innovations in the 20th century (World Bank, P.6), all of which emanated from developed countries, with the U.S. responsible for 60%, the U.K. 14% and Germany 11%.

In recent years, there have been some increases in the technological capacity of developing countries. This change is associated with rising expenditures on research and development, and is demonstrated by incipient exports of technology and capital goods from some developing countries. But much of LDCs research and development has been unsuccessful. Although scientific progress in a country may contribute to innovation and facilitates the application of science to production, scientific progress by itself is not adequate for technological progress. The scientific progress must be converted into industrial applications which are, in turn, made commercially viable through managerial know-how.

In the LDCs there are weak links between research and local productive activities. A very small proportion of total

Table 2-2 National Expenditures on Research and Development as a Percent of GNP

Year	United States	West Germany	Japan	France	United Kingdom	Soviet Union
1970	2.57	2.06	1.85	1.91	2.07	3.28
1971	2.42	2.19	1.85	1.90	NA	3.46
1972	2.35	2.20	1.86	1.90	2.11	3.71
1973	2.26	2.09	1.90	1.76	NA	3.81
1974	2.23	2.13	1.97	1.79	NA	3.74
1975	2.20	2.22	1.96	1.80	2.19	3.78
1976	2.19	2.15	1.95	1.77	NA	3.61
1977	2.15	2.14	1.93	1.76	NA	3.54
1978	2.14	2.24	2.00	1.76	2.24	3.54
1979	2.19	2.40	2.09	1.81	NA	3.59
1980	2.29	2.42	2.22	1.84	NA	3.76
1981	2.35	2.44	2.38	2.01	2.41	3.75
1982	2.51	2.59	2.47	2.10	NA	3.68
1983	2.56	2.54	2.61	2.15	2.25	3.82
1984	2.59	2.52	2.61	2.25	NA	3.95
1985	2.69	2.67	2.77	2.31	2.42	3.74
1986	2.72	2.74	NA	2.41	NA	3.79
1987	2.77	NA	NA	NA	NA	NA

Source: Science & Engineering Indicators, 1987

Note: NA= Not Available

research is conducted by firms. Even where local research efforts generate viable technologies, there is a strong tendency for these technologies to be rejected in favor of foreign produced techniques. This rejection is largely due to the market power bestowed by foreign trademarks, in turn engendered by a consumer belief that foreign is best, and by some bad experiences with the application of local technologies.

2.2 The Importance of Technical Change

Agricultural development is perhaps the most critical problem facing underdeveloped countries. The bulk of the population in these countries depends on agriculture for its livelihood. Economic advance in these countries can not proceed without substantial expansion of agricultural output and improvements in productivity.

Agricultural productivity is often low because of resource constraints and technological stagnation. For most LDCs, labor is abundant and land is scarce. In the past three decades, significant advances have been made in developing agricultural technology in DCs, but most of the LDCs are still using traditional farming skills. The reasons for technological stagnation can be grouped into five main categories: the lack of an appropriate alternative technology;

the lack of enough capital to adopt new technology; farmers' ignorance of better methods; the risks and costs of adoption; and barriers to adoption due to other market failures.

Successful growth in agricultural productivity depends on an ecologically adapted and economically viable agricultural technology. There is clear historical evidence that technology has been developed to facilitate the substitution of relatively abundant (hence cheap) factors for relatively scarce (hence expensive) factors of production. The constraints imposed on agricultural development by an inelastic supply of land could be offset by the development of high-yielding crop varieties designed to facilitate substitution of fertilizer for land. The constraints imposed by an inelastic supply of labor could be offset by technical advances leading to the substitution of mechanical power for labor. Productivity differences in agriculture become a function of investments in scientific and industrial capacity and in the education of rural people rather than of natural resource endowments.

Generally speaking, technological improvement creates a new production function such that any given quantity of resources yields a larger product. This is commonly conceptualized in graphical terms as a shift of the production function. In Figure 2.1, X represents variable input and Y represents output. The functional relationship between X and Y depends upon the choice of technology, with F2 representing

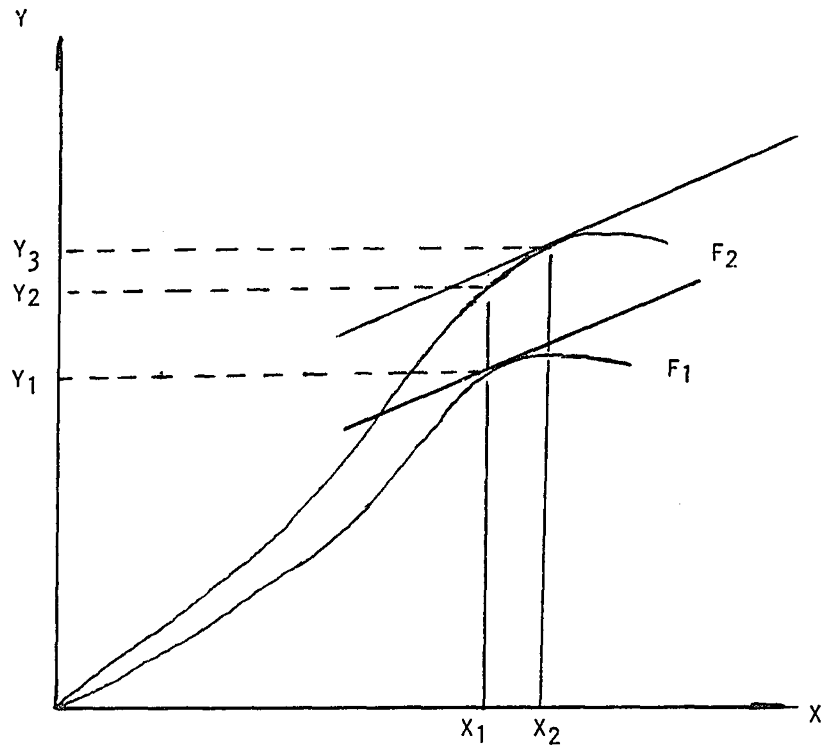


Figure 2-1: Effects of Technological Improvement on the Production Function

an improvement on F1.

Suppose F1 represents a function with a traditional rice variety and F2 a new and higher yielding variety. X is the input of fertilizer and Y is the yield of rice. The new variety is more responsive to fertilizer than the traditional variety in two ways. The yield per unit of fertilizer is higher; in Figure 2.1, a given fertilizer application of X1 yields Y2 of the new variety, which is higher than Y1. Second, the economic response to fertilizer extends to a higher rate of application; in Figure 2.1, the optimum application of fertilizer increases to X2, with a higher yield, Y3.

Technological progress can be beneficial to both individuals and society. Producers adopting improved techniques of production benefit, at least in the short run, because these "early-bird" farmers have a very small influence on total market supply and price. As more and more farmers adopt the new technology, however, total market supply will increase, causing price to fall. The gains in profit to the adopters of the technology are eliminated. In the long run, consumers and the nation stand to gain from increased aggregate supplies, either through the relief of actual physical scarcity, lower prices, or both. The consumers' gain is shown by the increased consumer surplus, area P1E1E2P2 , in Figure 2.2.

Because of the importance of technical change in agricultural development, many LDCs have searched for new ways

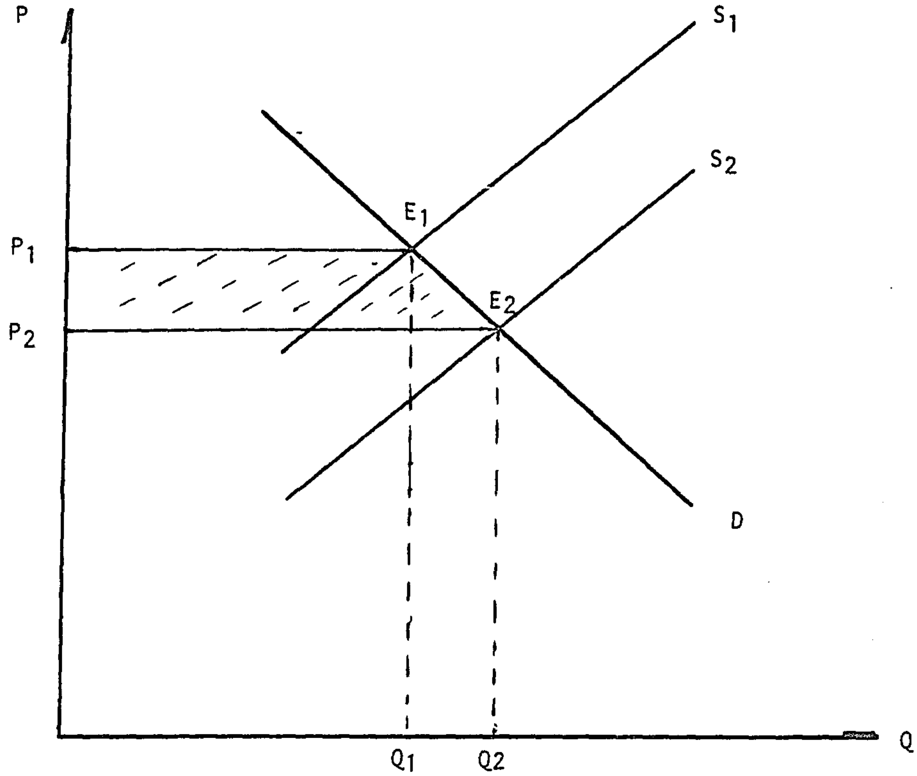


Figure 2-2: The change in consumer's surplus from a price decrease

to improve local agricultural methods. But limits to financial capital and research capacity have made it difficult to generate new technology. The production of modern innovations is large in scale, has long time horizons, and is knowledge intensive, particularly for biological innovations. Because of financial constraints, developing countries seldom undertake the research and development necessary to develop many new technologies in agriculture. Thus the possibility of international transfer of agricultural technology has appeared as an attractive method to solve the problem. Technological change in the agriculture of developing countries was originally a matter of importing new seeds, animals and equipment from industrialized countries. Over time, the methods of plant science, animal husbandry and machine design have also been transmitted and used to develop agricultural materials suited for local conditions in the developing countries.

The Chinese economic reforms of the past decade, for example, put emphasis on technological renovation. A great deal of equipment and technology has been imported from abroad. The old "closed" economy has been opened. Foreign trade and various forms of economic cooperation have flourished. The number of Sino-foreign joint ventures or solely-owned outside ventures has reached almost 10,000 and foreign investment now amounts to U.S. $42.6 billion. All of these changes have brought modern technology and new ideas to

China's agriculture.

2.3 Alternative Transfer Mechanisms

By what means is agricultural technology transferred internationally? Probably the most convenient and most successful institutions are the International Agricultural Research Centers. The second predominant means of transfer is a direct investment by a multinational firm in a wholly or majority-owned subsidiary. A third arrangement is a joint venture with minority participation by a foreign firm. The fourth form is licensing without any equity participation. The various sources of technology transfer all have different strengths and limitations, and different costs or benefits. The alternative vehicles afford a big range of choice, and greatly facilitate the international technology transfer process.

The process of international technology transfer can be divided into three stages. Material transfer is characterized by the simple import of new materials such as seeds, machines and animals. Design transfer includes such materials as blueprints, formulas, and books. Capacity transfer is made through the transfer of scientific knowledge. At this stage, the transferred technology enables the production of locally adaptable technology. Plant and animal varieties are bred locally to adopt them to local ecological conditions, and imported machinery designs are modified to meet climatic and soil requirements and factor endowments of the economy.

The most dramatic example of agricultural technology transfer during the last several decades has involved the development and rapid diffusion of modern high-yielding varieties of rice, wheat and other cereals. It was made possible by a series of institutional innovations in the organization, management, and financing of agricultural research in the less developed countries. The international research system grew rapidly during 1960's and 1970's. The structure of the international agricultural research network is shown in Table 2-3.

Multinational enterprises, joint ventures and licensing arrangements, which are typically industrial technology transfer methods, are also very useful vehicles for the transfer of technologies for fertilizer, crop, and livestock processing equipment, and agricultural machinery, such as machines for land preparation and harvesting. For example, in recent years, China has transferred a lot of technologies for fertilizer production and food processing under joint venture arrangements.

Technology transferred through full or majority foreign equity participation is usually a complete package. In addition to product design and production know-how, the foreign parent enterprise typically contributes management

Table 2-3 Structure of International Agricultural Research Network, 1984

Center	Location	Research	Core Budget for 1984 ($000,000)
IRRI (International	Los Banos, Philippines	Rice under irrigation, multiple cropping systems; upland rice	22.5
CIMMYT (International Center for the Improvement of Maize & Wheat)	El Batan, Mexico	Wheat; maize	21.0
ITTA (International Institute of Tropical Agriculture	Ibadan, Nigeria	Farming systems: cereals; grain legume; root & tuber crops	21.2
CIAT (International Centre for Tropical Agriculture	Palmira, Colombia	Beef; cassava; field beans; swine (minor); maize & rice (regional relay stations to CIMMYT & IRRI)	23.1
WARDA	Monrovia, Liberia	Regional cooperative effort in adaptive rice research among 13 nations with IITA & IRRI support	2.9
CIP (International Potato Centre)	Lima, Peru	Potatoes	10.9

Table 2-3 (Continued)

Center	Location	Research	Core Budget for 1984 ($000,000)
ICRISAT (International Crops Research Institute for the Semi-Arid Tropics)	Hyderabad, India	Sorghum; pearl millet; pigeon peas; chickpeas; farming systems; groundnuts	22.1
IBPGR (International Board for Plant Genetic Resources)	Fao, Rome, Italy	Conservation of plant genetic material with special reference to crops of economic importance	3.7
ILRAD (International Laboratory for Research on Animal Diseases)	Nairobi, Africa	Trypanosoiasis; theileriasis	9.7
ILCA (International Livestock Center for Africa)	Addis Ababa, Ethiopia	Livestock production system	12.7
ICARDA (International Center for Agri. Research in Dry Areas)	Lebanon, Syria	Crop & mixed farming systems research with focus on sheep, barley, wheat, broad beans, & lentils	20.7
IFPRI (International Food Policy Research Institute)	Washington, D.C. United States	Food policy	4.2
ISNAR (International Service for National Agri. Research)	The Hague, Netherlands	Strengthening the capacity of national agricultural research programs	3.5

Source: Yujiro Hayami & Vernon W. Ruttan: AGRICULTURAL DEVELOPMENT-AN INTERNATIONAL PERSPECTIVE. (The Johns Hopkins University Press, 1985) PP.268-269 and marketing services.

International movement of equipment and proprietary technology may also result from the setting-up of joint ventures between firms in two countries. The firms, or frequently the governments of the recipient countries, own a majority of the share capital. This type of transfer has attracted great interest in developing countries for both economic and political reasons. The motivation is complex, including the objective of greater local control of the enterprise and acquisition of a larger share of profits. It also includes the objective of training in the sense of learning managerial skills by participating in the board of directors and top management. Although such arrangements face all the well-known risks of partnerships (the relationship may be dissolved because of disagreements, but the transfer can not be reversed), they are often the most feasible way of cooperation between firms in capitalist countries and the state-owned enterprises in the socialist countries, such as China.

There is typically a difference in the nature and timing of costs associated with joint ventures and controlled subsidiaries of multinational enterprises. Generally, the dividend payments of joint ventures are higher during the early period and more uniform over time than the payments of foreign-controlled subsidiaries. Another difference lies in the degree of access to export markets. The foreign-controlled subsidiary is more likely to be offered access to global distribution channels of the foreign firm than is a joint venture.

Developing countries often consider the acquisition of technology through licensing arrangements without foreign equity participation to be the ideal procedure. The licensee's firm usually requires that the price of the technology be fixed in advance. Rather than paying an unpredictable or unending flow of dividends, the firm pays a stream of fees, usually based on sales volume. Normally, the period over which the payments are made is limited. But the licensing arrangements generally call for the supply of only a limited part, not a complete package, of technical skills. Furthermore, whether associated with patents or not, licenses frequently serve as vehicles for restrictive business practices by the supplier not only with respect to export but also with respect to other aspects of business operations, such as the volume of output (Chudson).Licensing arrangements are most common for mature and widely-held technology, and for countries whose internal market is large enough to offer an attractive reward.

2.4 Conclusion

Three conclusion points come out of this discussion.

Uneven economic development leads to differences in research and development capacity, causing technology gaps and creating the possibility of international technology transfer. The developed countries have a vast stock of technical knowledge, and the less-developed countries have little. Second, technology is a very important factor in modern agricultural development. Without new technology, the less-developed countries can not break away from poverty and backwardness. The best way to get a new technology with lower costs per unit of output often involves transfer from an industrialized country. Third, several alternative transfer mechanisms are available to facilitate transfer activities.

CHAPTER 3

PROBLEMS ASSOCIATED WITH AGRICULTURAL TECHNOLOGY TRANSFER

Many developing countries benefitted from international transfer of agricultural technology. But some undesirable effects accompanied this transfer activity. Initially keen to industrialize agriculture, most countries tried to maximize the quantity of technology transferred. They introduced a host of incentives, such as tax exemptions, duty refunds and the provision of infrastructure. However, such indiscriminate importation caused some inappropriate technologies to flow to LDCs, and sometimes it also created disincentives to develop local technological capacity. In some cases, technology transfer may have aggravated inequality in the distribution of income because large farms had better access to new technologies and were more able to capture the benefits from adoption.

3.1 Choice of Appropriate Technology

The characteristics of new production technology are largely determined by the economies for which they are designed. The economies of advanced countries differ from those of poor countries. Consequently, some economists (World Bank, No.344 and National Research Council, April 1977) think technology recently developed in advanced countries tends to be inappropriate, usually because it is too capital intensive. The transfer of such technology to poor countries tends to cause various distortions and inefficiencies.

The key problem here is the definition of appropriate technology. The most significant feature of modern agriculture in advanced countries is the use of large scale mechanical equipment in order to save labor. This is because the opportunity cost of labor is high. Most LDCs are short of capital and abundant in agricultural labor. As shown in Table 3-1, the agricultural labor force in the LDCs has increased in the last several decades. In contrast, it decreased rapidly in the DCs--at a rate of nearly 4% per year.

The rate of growth in the agricultural labor force in the LDCs accelerated from 0.6% during the 1960-1970 to 1.9% during the 1970-1980. This acceleration resulted mainly from accelerated growth in total population during the first two decades after World War Two. Another important factor underlying the rapid growth in the agricultural labor force was the slow rate of growth in the industrial sector.

In this situation, a labor-saving mechanical technology, designed to meet the needs of advanced countries, may be

Table 3-1 The Rate of Growth in Population, Agricultural Labor Force, and Agricultural Land by Country Group

1960-1980 (Percent Per Year)

	Population	Agricultural Labor Force	Agricultural Land	Land-Labor Ratio
Developed Countries				
1960-1970	1.0	-3.8	-0.3	3.5
1970-1980	0.6	-3.8	-0.4	3.4
1960-1980	0.8	-3.8	-0.3	3.5
Middle-Stage Countries				
1960-1970	2.2	-1.1	0.3	1.4
1970-1980	1.9	-2.0	0.3	2.3
1960-1980	2.1	-1.5	0.3	1.8
Less Developed Countries				
1960-1970	2.6	0.6	0.5	-0.1
1970-1980	2.4	1.9	0.4	-1.5
1960-1980	2.5	1.2	0.4	-0.8

Soure: Adapted from Yujiro Hayami and Vernon Ruttan, AGRICULTURAL DEVELOPMENT Page 418 (1985 The Johns Hopkins University Press) inappropriate in an LDC economy. In low-wage economics, labor-intensive processes, if feasible, will be lower-cost technologies. Mechanized agriculture requires substantial capital resources, high levels of investment per worker and high levels of education and skills, as well as sophisticated management techniques. It is often difficult for the LDCs to deal with these requirements.

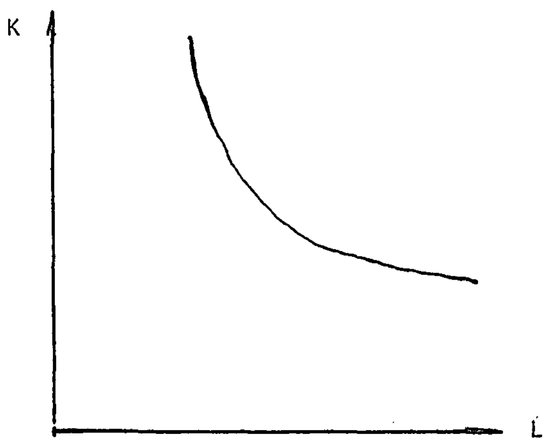
Biological change is another significant feature of modern agricultural technology. Improved seeds and animal breeds have played a major role in recent productivity growth. Since agricultural production is based on biological processes, it is affected by differences in soil qualities, temperatures, and water availability. Because of this environmental sensitivity, the seeds or animal breeds developed in a certain region may not perform well in other regions. The process of transfer therefore requires the adaptation of crops, animals and farming systems to the environmental conditions of individual countries.

Fertilizer, herbicides and insecticides are the major types of chemical technology of relevance to agriculture. A lot of high-yielding varieties are distinguished by high fertilizer responsiveness. Often, their fertilizer-responsiveness is fully realized only when accompanied by improved husbandry practices(for example, weed and insect control) and adequate water control. Many LDCs are short of fertilizer and have inadequate irrigation systems. The transferred high-yielding seeds could not realize their potential efficiency in such conditions. Traditional varieties may still represent an optimal technology since they can survive with little fertilization and under unfavorable environmental conditions.

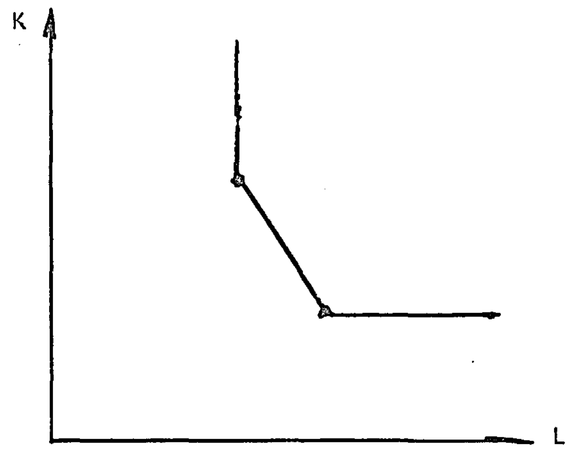
Therefore, LDCs must pay attention to the choice of appropriate technology. But what is an appropriate technology? As a basic answer, many authors say that the fundamental requirement of an appropriate technology is that it makes optimum use of the available resources in a given economic environment. Furthermore, through the use of "shadow price" and benefit-cost appraisal criteria, economists have been trying to devise choice mechanisms that would permit individual choices to be made consistent with the maximization of social welfare. Finally, the appropriate technology should be a dynamic concept. A new technology may not be appropriate in the current time period, but may be useful in the future.

Appropriate technology refers to the correct choice among technical alternatives. To demonstrate this process of choice, it is convenient to assume the existence of a production function that, in the forms of isoquant diagram, combine capital, labor and all other inputs to produce a given amount of output. Capital-labor substitution is shown in Figure 3.1. Some production activities have infinite number of possible technologies. In this situation, there are flexible substitutions. For example, a lot of farm work could be done

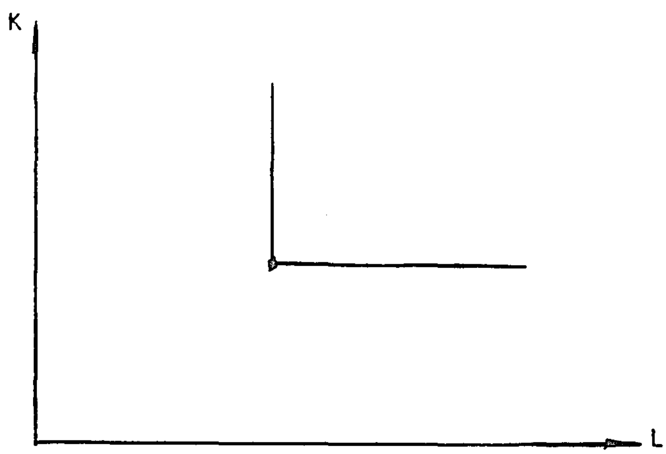
Figure 3-1



Part A: Flexible substitution, there are infinite number of possible technologies



Part B: Limited substitution, only two possible technologies



Part C: No substitution, only one possible technology availiable manually as well as mechanized or semimechanized. A good choice will be made according to the ratio of labor and capital prices. But some production activities have a limited number of alternative technologies. As shown in Figure 3.1, parts B and C, there is little choice in these situation. One particular combination of inputs will be lowest cost under a wide range of factor prices. Available technology is appropriate technology since there is no feasible substitution. So, depending on nature of technical alternatives and relative input costs, DC techniques may or may not be appropriate in LDCs. A blanket condemnation of technology, just because it is capital-intensive, is clearly an "inappropriate" judgement.

3.2 Disincentives to Local Innovation

Some economists have argued that unrestricted importation of technology inhibits the development of local research and development capacity, that in turn reduces long-run development prospects and engenders further technological dependence (Stewart). Foreign technology associated with foreign trademarks tends to have a strong market advantage over local technology, because technologies and products from developed countries are often thought superior to the domestic product. For example, Chinese farmers prefer to use fertilizer imported from Japan or produced by joint ventures. They think Japanese fertilizer is much higher quality than the alternatives.

Technological development is often considered an infant industry that requires protection. Policies to protect and promote local technological development involve the selective import of foreign technology as well as promotional measures for domestic development. While there appears to be a certain amount of technological choice today, the continued concentration of technical change in advanced countries is likely to result in increasingly inappropriate techniques for LDCs. Unless developing countries undertake research and development, the choice of technology available in the future will be increasingly irrelevant to the needs of the world's poorest people.

The development of local technological capacity may be classified as a three stage process. In the first stage, the capacity for independent search and choice is developed; in the second, minor technical changes, which may add up to major changes in terms of quantitative impact, are generated locally; in the third, new technology is developed endogenously. The third stage is unlikely to occur unless the first two are well established. The impact of foreign technology inflow is likely to be different according to the stage reached. In the first two stages, local development may benefit from foreign knowhow since the imported technology serves as an example to be copied and studied. But at the third stage, unregulated technology inflow may inhibit or delay domestic innovations.

Technology transfer from developed countries may or may not be a disincentive to local technological innovation, depending on the control and use of it. Japan's industrial technological development is a very successful example of this sort of policy: technology was imported, then adapted domestically and promoted in both public and private sectors. The development of fertilizer in India is also a good example. Before the 1950's, India didn't have its own fertilizer industry. Agriculture depended on farm manure. After the importation of modern chemical fertilizer techniques from Japan and British, India developed its own chemical fertilizer production capacity.

3.3 Polarization in Rural Communities

Some critics argue that the gains in agricultural production from technology transfer have been offset by a deterioration in equity--the new technology makes the rich richer and the poor poorer (Pearse). In this process, large farmers and landlords have better access to new information and better financial capacity, whereas small farmers have difficulty to use modern technologies efficiently because financial constraints make it difficult for them to purchase cash inputs such as fertilizers and chemicals. Monopoly of the new technology by large farmers give them more profits that are used to buy small farmers' holdings, and as farm size increases it becomes profitable to purchase large-scale machinery and reduce the cost of labor management. The effect is to reduce employment opportunities and to lower wage rates for the growing number of landless workers.

But some economists argue against this opinion (Hayami and Ruttan). It was said that mechanical-engineering and biological-chemical technology have different income-distribution effects. Because biological technology saves land by applying labor and biological inputs more intensively, its diffusion might be expected to contribute to a more favorable income distribution in rural communities. There is a large body of evidence that suggests that biological technology has not been monopolized by large farmers. An international project coordinated by the International Rice Research Institute studied the changes in rice farming in selected areas of Asia. Farms were grouped under three size classes: large, medium and small. The results showed that small farmers adopted the modern varieties technology even more rapidly than large farmers. A study of the adoption of modern wheat varieties in the Indian Punjab showed that MV wheat represented a neutral technological change with respect to farm scale--both small and large farms achieved approximately equal gains in efficiency (Sidhu).

The argument about the relationship between technological change and income distribution appears to be more of an ideological debate than a description of contemporary development experience. The problem is not technology transfer itself, but the ways that the benefits are distributed. It depends on how well small farmers can be organized to take the advantage of new technologies and capture potential economies of scale. Technology improvement is a necessary condition for agricultural output and productivity growth. Inequity is relative, but new technology can make all people better-off in absolute terms. The gains have gone both to the poorer and the wealthier. If developing countries fail to achieve sufficiently rapid technological progress, greater poverty will be the inevitable result.

An example of contrasting effectiveness is provided in a study of the adoption of tube wells in Bangladesh and Pakistan (Eckaus). The study showed that in Bangladesh, where there are many small-scale farms, the use of tube wells facilitated the formation of village cooperatives. In Pakistan, cooperatives were not formed. Large landlords used their political power to obtain subsidized credit for tube wells offered by the government, leaving small farmers at a disadvantage. Thus the different social and political patterns effected the way technology was used and how the benefits were distributed. In this situation, there is no reason to blame new technology. It is the institutions that cause the polarization.

3.4 Conclusion

The problems accompanied with agricultural technology transfer are not problems of the technology transfer itself, but instead reflect the influences of local institutions. The central questions for the economics of technology transfer are which technologies will be transferred, how they will be modified in the development of local technological capacity, and how the distribution of benefits from new technology can be managed. The successful transplant of a technology involves the correct choice, the domestic capacity to alter, modify and adopt in different ways, and institutions that can distribute the benefits in an equitable manner.

CHAPTER 4

THE IMPACT OF AGRICULTURAL TECHNOLOGY TRANSFER UPON THE DONOR COUNTRY

This chapter discusses the costs and benefits of technology transfer for the donor country. As an export activity, technology transfer opens a foreign market, and the technology donor gets direct profits from the transfer. The international export of agricultural technology also influences the donor country's farm export market. There are two different opinions about these effects. One view argues that in a static or short-run view, the donor country may lose its export market because of the recipient country's increased agricultural production. The second view argues that, in the long-run, the donor country may increase exports because the technological change in the recipient country creates multiplier effects on the rest of the economy that lead to increased agricultural imports. Both of these arguments consider only the donor country producer's gains or losses. What also needs to be considered is the effect on the donor country's consumers. Technology transfer may bring imports to the donor country that benefit consumers.

4.1 Technology Transfer and Producer Surplus

International technology transfer opens a foreign market and brings back profits to the donor country. Usually the technology producer is the direct beneficiary. The producer would benefit from technology transfer because exports reflect increased demand, especially for those technologies that have saturated the domestic market.

The most common approach in empirical and theoretical work to compute producer gains is to determine the change of producer surplus. Alfred Marshall defined producer surplus as the area above the supply curve and below the price line of the corresponding firm or industry. This geometric area represents his quasi-rent concept, which defines a producer's net benefit as the excess of gross receipts that a producer receives for any commodities produced over his prime cost--the marginal cost that the firm incurs.

The concepts illustrated in Figure 4.1 With technology transfer activity, the demand curve in the agricultural input market shifts outward and the equilibrium price increases from Po to P1. The price change brings an increase in producer surplus which is indicated by the area P1PoWX in Figure 4.1.

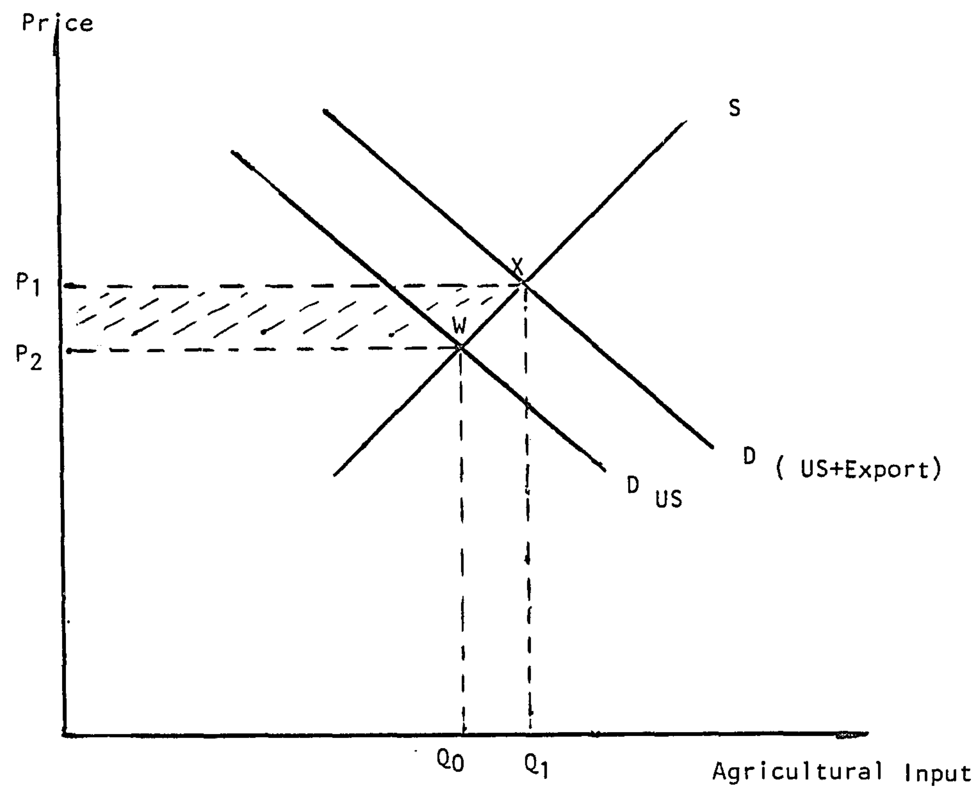


Figure 4-1: The exportation of agricultural production input shifted the demand curve outward and increased the equilibrium price from P_0 to P_1. The net producer surplus change was indicated by area P_1P_2WX.

4.2 Influence on Donor Country's Farm Export Market

There has been an intense argument both in policy-making circles and among economists as to whether or not assisting agricultural development in the less-developed countries hurts the donor country. The principal controversy concerns the effect on the donor country's farm export market.

The view that the donor country would lose from agricultural growth in less-developed countries argues that global demand is fixed and another country's increased production or exports must come at the expense of the donor country's exports. Thus any technology export, consultancy or training in connection with the growth of farm production in a foreign country directly or indirectly competes with the production in the donor country. For example, Brazilian soybeans and Malaysia's palm oil compete with U.S. soybean exports.

This argument focuses only on the developing country's supply conditions. The simple way to present it is with the help of Figure 4.2, which shows the domestic demand and supply curves for staple food in a developing country. In the absence of distorionary price or trade policies, the world price Pw will also be the domestic price. The country will consume C units, of which Q will be produced domestically and $\bar{QC}$ will be imported. With the improvement in technology, the supply curve will shift to S', domestic production expands to Q' and

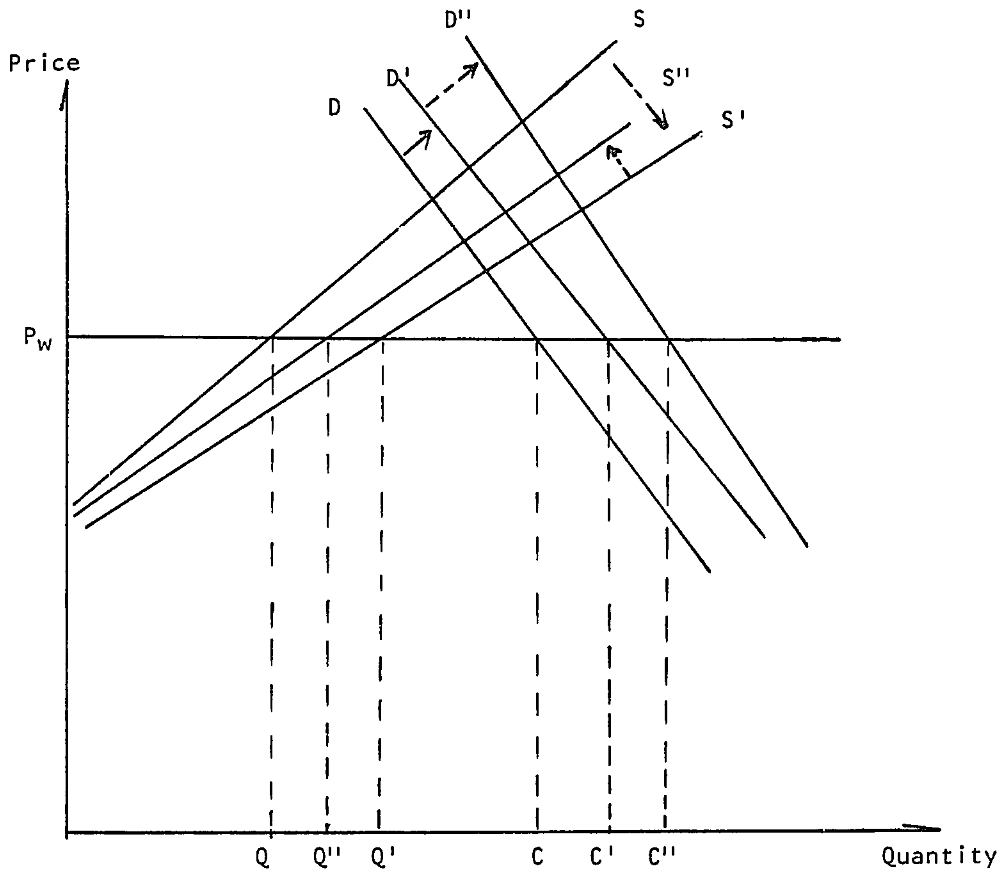


Figure 4-2:

A developing country's market for staple food imports fall to Q'C. The reduced food imports thus affect the donor country's export earnings. If this kind of change happens in enough developing countries, the Pw may fall and again affect the donor country in a negative way.

Another view argues that food demand is not fixed in the long-run. Assisting LDC agriculture creates multiplier effects for the rest of economy that lead to rising food or feed imports. When farmers adopt a new technology their income increases. Part of that increase is spent on extra inputs and the rest is available to spend on consumer items or to invest. Thus, the demand for agricultural products shifts to the right, to D' in Figure 4.2, as a result of farm income growth.

The increase in farm incomes also increases the demand for nontradables, products and services that can not be traded internationally. Since by definition such goods must be produced domestically, this requires a movement along the supply curve for nontradables, illustrated in Figure 4.3. The quantity of nontradables increases and so do their prices. This change has two important effects: less resources are available to produce traded products as labor and capital are drawn into nontradables' production, so the supply curves in Figure 4.2 shift to the left (S''); second, incomes increase for producers of nontradables. That is, the direct income boost for farmers due to the new technology generates a second round of effects due to the spending by producers of nontradables, shifting the agricultural product demand curve

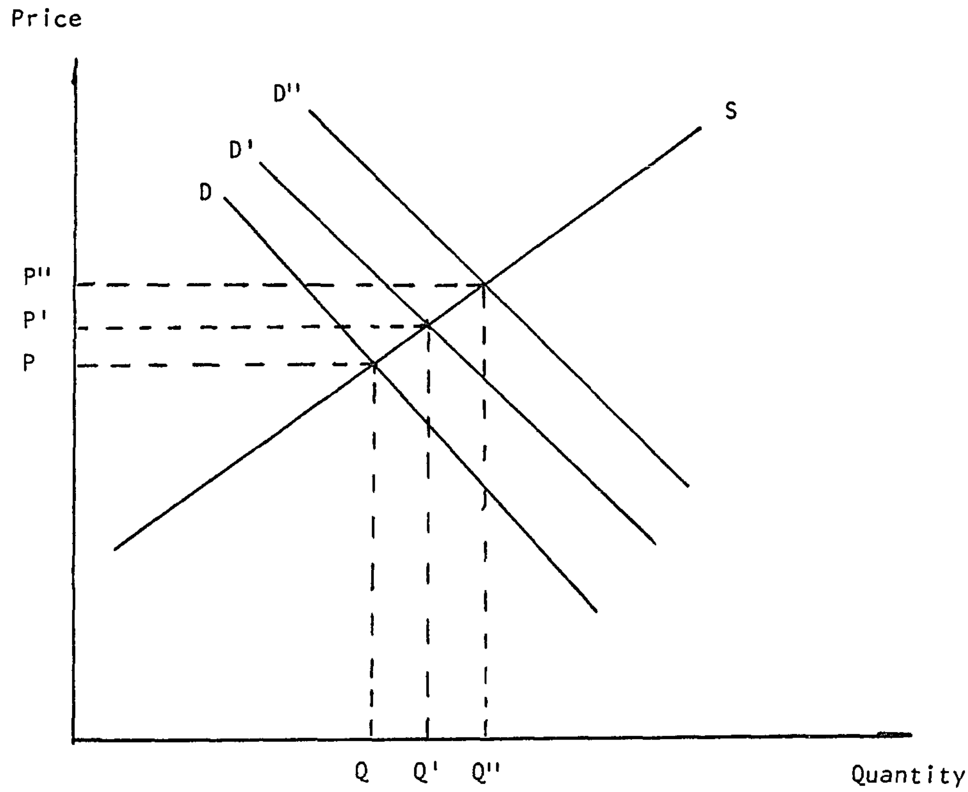


Figure 4-3:

A developing country's market for nontradables to D'' in Figure 4-2. The final result is that staple food imports for LDCs change from QC to Q"C" in Figure 4.2. But it is unclear whether that is an increase or a decrease. Only empirical research work can give the answer.

Several economists and trade analysts have elaborated on the long-run impacts of technology transfer on the farm export market. Kym Anderson provides a case study that shows farm output in China increased by more than 50% between 1978 and 1984. But China's share of the world markets for grain, livestock products and sugar increased from 12% to 17% over that period, because domestic demand growth outpaced the growth in domestic production (Anderson). Alain de Janvry also pointed out that during the last twenty years, there has been a significant relocation of the origin of import demand for food and feed grains away from the more developed countries and toward the centrally planned economies, the oil exporting countries and LDCs. Between 1961-1963 and 1981-1983, 63% of the growth in net imports originated in the LDCs, of which 41% was in the lowest-income countries. For feed grains, 49% of the growth in net imports originated in the LDCs. About 35% of this total was in the middle-income newly industrialized countries, because sharply rising incomes shifted consumption patterns toward animal products, accelerating increases in the demand for feed grains (Janvry and Sadoulet). Meanwhile, the LDCs have increased their share of U.S. exports from 35.1% in 1965-1967 to 40.4% in 1984-1985.

The key point of this exercise is to associate changes in import demand with economic growth and with agricultural growth. Alain de Janvry did an historical analysis of the performance of 42 LDCs between 1965 and 1981, where a positive association has been observed among agricultural growth, overall economic growth, and rising import demand for food and feed. About 73% of the countries with a strong agricultural growth performance also have a strong overall economic growth performance. Furthermore, countries with both strong agricultural and GDP growth have the highest annual growth rate in cereal import demand, especially for countries whose growth rate of GDP exceeded the growth rate of agriculture.

These results suggest that agriculture may be a necessary source of growth for most LDC economies but is not sufficient to ensure growth in import demand. Instead, agricultural growth has to be complemented by strong growth in the nonagricultural sectors. Countries with high agricultural and GDP growth rates and higher GDP growth rates than agricultural growth rates absorb the bulk of increased cereal exports. An econometric model made it possible to identify the levels of trade dependency and the composition of domestic agricultural growth that result in positive elasticities of import demand relative to agricultural growth.

In some situations, growth in incomes fails to lead to rising cereal imports, and sometimes the growth of agricultural output leads to increased food and feed grain self-sufficiency instead of rising imports. Therefore, the ultimate outcome is not easy to specify. Agricultural technology transfer is a risky strategy for the donor country. The long-run gains may or may not be sufficient to outweigh short-run losses.

4.3 Influence on Donor Country's Domestic Market

The above arguments are incomplete because the discussions are confined only to the affect of agricultural development in the LDCs upon donor country farm exports. They consider only the donor country's producer's welfare and ignore the effects on consumer's welfare. A increase in farm product exports will benefit donor country's farmer by increasing producer surplus, but hurts the consumer by decreasing consumer surplus.

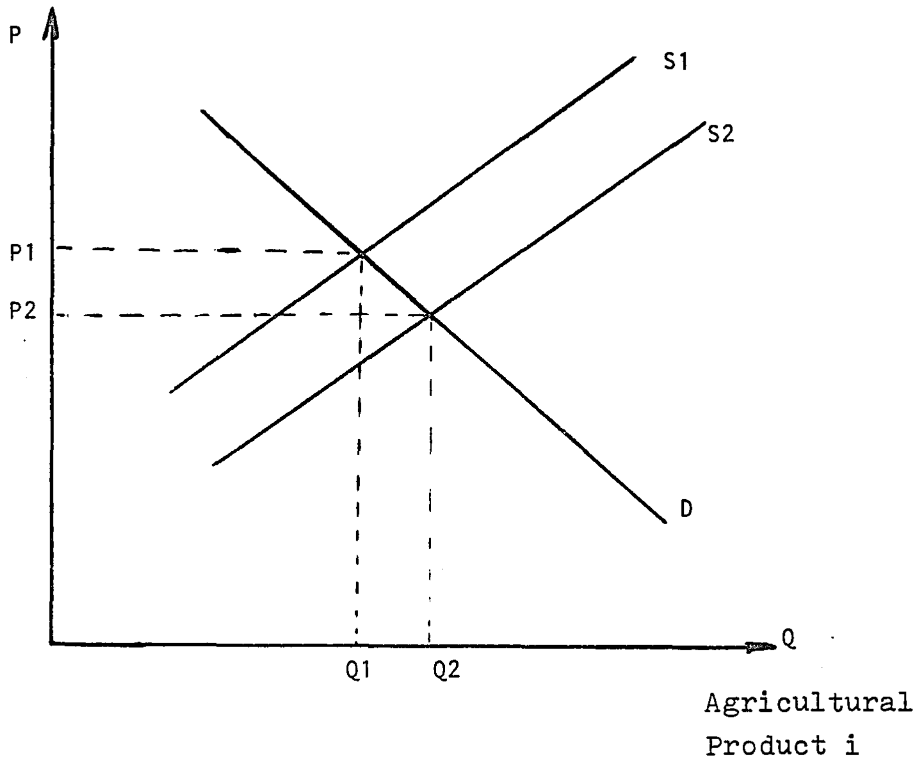
In addition, technology transfer that increases agricultural productivity in LDCs may also bring an inflow of desirable farm products to the donor country's domestic market. Due to resource endowments and the costs of productive factors (especially labor), recipient countries may have a comparative advantage and produce for export. Their exports increase the availability of agricultural products in the donor country and may affect the prices of those products in the donor country's domestic market. These imports can be expected to benefit consumers and harm domestic farmers. Even if the trade is not direct between the donor country and the recipient country, the world market price will be decreased from the increased production in LDCs, and the consumer will get the benefits.

An example is provided by the U.S.-Mexico agricultural technology transfer experience. The United States has supported technological change in Northwest Mexico through the transfer of irrigation equipment, farm machinery, improved seeds, fertilizers and pesticides. At the same time, the U.S. has imported winter vegetables from this area, benefitting U.S. consumers and harming Florida winter vegetable producers.

The economic benefits from technology transfer depend on whether the importation benefits the donor country as a whole. Net social gains or losses can be derived by using the concepts of consumer surplus and producer surplus. The inflow of farm products increases the supply in the donor country's market, and shifts the supply curve outward. In Figure 4.4 (A), the supply of agricultural product i shifts from S1 to S2. When this shift occurs, holding demand constant at D, the equilibrium price falls from P1 to P2, and consumption expands to quantity Q2.

The price change brings an increase in consumer surplus and a decrease in producer surplus. Consumer surplus is defined as the area under the demand curve and above the price line of the industry market. There are two reasons why the

Figure 4-4

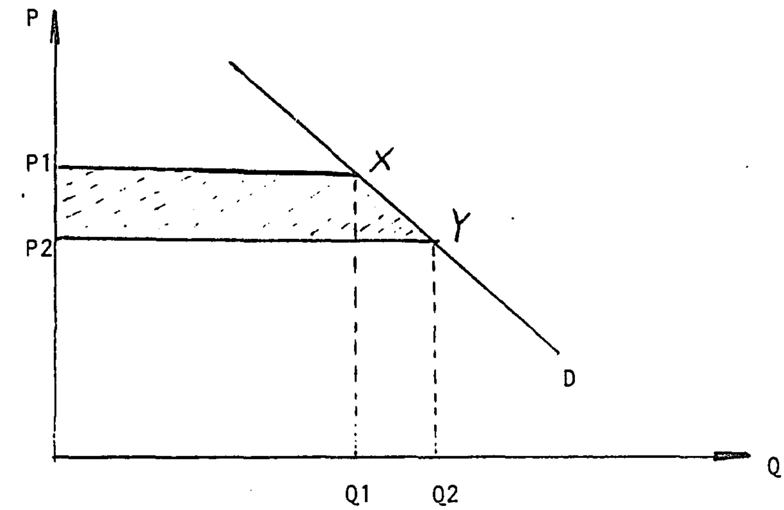


(A) The importation of farm product shifted the supply curve from S1 to S2 , and decreased the market equilibrium price from P1 to P2 change in consumer surplus is appealing as a measure of consumer benefits: first, it represents the sum of cost differences as price is continuously reduced from P1 to P2; alternatively, it gives the change in what the consumer is willing to pay over that which is actually paid with the price change. The latter concept considers the demand curve as a marginal willingness-to-pay curve, postulated by economist Jules Dupuit. The price associated with any quantity on a consumer's demand curve is the maximum price that the consumer is willing to pay for the last unit consumed.

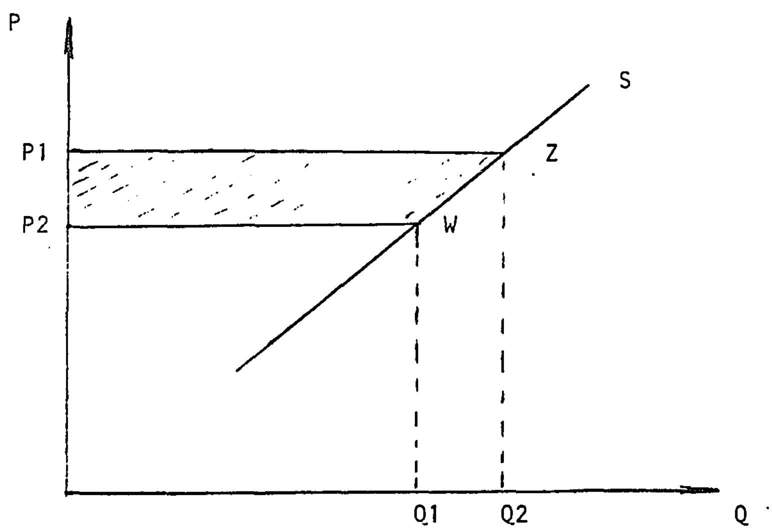
In Figure 4.4 (B) and (C), area P1P2XY represents the positive change of consumer surplus, and the area P1P2ZW represents the negative change of producer surplus. Estimating the size of these two areas and comparing them gives the estimate of net national gain or loss.

Two assumptions should be emphasized. First, the demand curve is "Marshallian", which simply shows quantity demanded against price, not a "compensated" demand curve of the kind introduced by Hicks, which shows demand as income is varied to keep the consumer at the same level of utility. The reason for reliance on the Marshallian measure is partly because of empirical measurement difficulties and partly because the errors are not large. Second, calculation of the change in consumer surplus for only one good is used as a measure of the benefits of the importation activity. As the price of the good in question falls, it may well alter the demand curves for

Figure 4-4 Continued



(B) The decreased price gives consumer additional benefit which is indicated by the increased consumer surplus P_1P_2XY



(C) The falled price brings loss to farmers which is indicated by the decreased producer surplus P_1P_2ZW

other products which are substitutes or complements. But these changes may be ignored because these affects are also small in magnitude.

4.4 Conclusion

This chapter provided a brief theoretical discussion of the impact of agricultural technology transfer upon donor country. It is hard to say whether gains are positive or negative since the influence on the donor country's farm export market is unclear and the net change of producer and consumer surplus may be of any sign. To enrich the discussion of the impact of technology transfer on the donor country, the second part of this thesis focusses on an empirical analysis of the costs and benefits from the transfer of agricultural technology from the United States to Northwest Mexico.

CHAPTER 5

ANALYSIS OF THE U.S.--NORTHWEST MEXICO TECHNOLOGY TRANSFER

Northwest Mexico's agriculture has benefitted from imported technology since the 1950s. The United States is by far the largest supplier to Mexico of farm machinery, improved seeds, fertilizers and pesticides. The transferred agricultural technology has helped this area to provide a big share of the U.S. winter vegetable supply, competing against Florida winter vegetable producers and benefitting U.S. consumers. This chapter will estimate the U.S. producer and consumer surplus changes that have been associated with the transfer of agricultural technology.

5.1 Technology Transfer and Northwest Mexican Agriculture

Over the past three decades, Northwest Mexico has experienced substantial growth in the production of agricultural commodities. Wheat, cotton, livestock, vegetables and sugarcane have been the most prominent commodities on an irrigated area of more than two million acres. Most of this growth resulted from the wide use of material inputs, in particular irrigation systems, improved seeds, fertilizers, pesticides, and farm machinery. These new technologies have been mainly transferred from the U.S. The combination of improved seeds and increased water availability made profitable the utilization of chemical fertilizers. Moreover, the creation of larger irrigation districts encouraged the expanded use of farm machinery. The greater speed at which machinery could operate, compared with the speed of animal-drawn implements, improved the timing of planting and harvesting and facilitated more precise control of sowing depths and spacing of seeds. Mechanization and the use of aircraft also made possible the widespread utilization of pesticides, contributing significantly to the improvement in crop yields.

The states of Sonora and Sinaloa comprise the Northwest region, extending from the watershed boundary of the Sierra Madre Occidental mountains to the Pacific coast, and from the international border with the United States to the San Pedro river in the state of Nayarit. Their irrigated cropland represents 30% of the total area covered by the publicly administered irrigation districts. These two states have the largest farms, and are distinguished from farms in other regions of Mexico by their substantial use of irrigation, hired labor and modern inputs. They sell a large proportion of their output through commercial channels. They contribute almost 14% of the total value of Mexico's agricultural output and utilize only 10.5% of the nation's harvested area. Sinaloa's contribution to the state's GDP remained almost constant at 25%. In absolute terms agricultural GDP grew at an average annual rate of 9.6%, while the rest of the state's GDP grew at a rate of 9.2%. But agriculture's relative contribution to GDP has decreased during the last two decades. Its stagnation has been attributed to water scarcity and pest problems, as well as to structural and economic impediments to increasing the area under cultivation.

Both states are major producers of grains, cereals, and oilseeds for domestic consumption, as well as vegetables, cotton, and chick-peas for export. There are thirteen major crops. Staples include corn, wheat, beans and sorghum. Sinaloa also produces some rice. Oilseeds include soybeans, safflower, and sesame. Vegetables are mainly tomatoes and green peppers. Cotton and chick-peas, as well as alfalfa, are also widely grown in both states. The production is a function of climatic conditions, adoption of improved technology, and the quality of agricultural land.

The significance of vegetable crops in both states lies mainly in their contribution to the total value of output. Vegetables occupy 1% and 4% of irrigated area in Sonara and Sinaloa respectively, but their relative contributions to total value of production are 7% and 35%, respectively. Vegetable area has expanded, and farmers' organizations have had to act cooperatively to restrict vegetable area in recent years. Relative increments in vegetable production have been greater in Sonora than in Sinaloa. Yield increments have also played a major role in increased production.

Vegetable production technology represents all the features of mechanized modern agriculture. Improved seeds are supplied by the state-owned National Seed Producer and commercial firms. Tomatoes and green peppers are germinated inside greenhouses under controlled environmental conditions and then transplanted into the field. This procedure makes a more efficient use of the mostly imported seed and yields stronger and healthier plants. It also permits an early start of the crop in cases when the field is still occupied by another crop.

Pesticides are widely used for the prevention and control of insect pests and diseases. Applications are mostly aerial, although manual and ground mechanical spraying are also practiced. Chemical fertilizers are commonly used and usually applied twice, before or during planting, and before the first or second cultivation. Applications are mostly mechanical. Harvesting of most crops is mechanized. Combines are used for harvesting and threshing corn, wheat, rice, sorghum, soybeans, safflower and chick-peas. Cotton is mostly harvested mechanically in Sonora, and manually in Sinaloa. All vegetables are harvested manually.

Finally, the organization of marketing pools is common in both states, especially for export crops like vegetables, cotton and chick-peas. Advance sale contracts between farmers and industry or wholesalers is also common for rice, cotton and vegetables. Tomatoes and green peppers are selected and packed by local processing plants. Products that meet export quality requirements are precooled and transported to Nogales, Sonora, the main port of exit to the United States.

5.2 Benefits to U.S. Agricultural Input Producers

The market for agricultural machinery, related equipment and materials in Mexico has grown very fast since the 1960s. The United States is the largest supplier of production inputs for Mexican agriculture. As discussed above,the U.S. agricultural input producer is a direct beneficiary from technology transfer. This section is devoted to estimating the U.S. producer surplus from the agricultural technology transfer activity.

Figure 5.1 illustrates the effects on an input market from demands induced by technology transfer. Mexico's imports add to the demand for U.S. agricultural inputs, shifting the demand curve outward. Holding the supply curve unchanged, the shift in the demand curve brings a higher price for the U.S. input producer, and therefore a positive change in producer's surplus, indicated by area P*PoBC. The increased

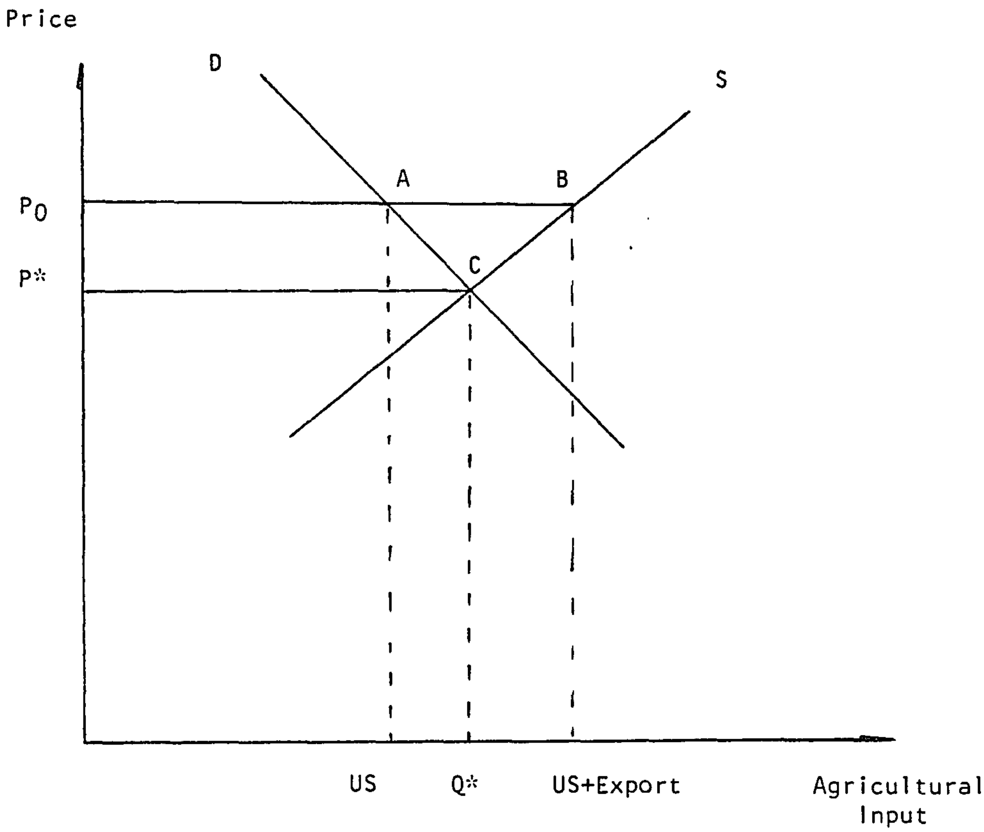


Figure 5-1

The Effect of Agricultural Input Export on Net Social Benefits, Producer Surplus, and Consumer Surplus price of inputs has a negative impact on U.S. domestic consumers, indicated by area P*PoAC. However, the net surplus change for the U.S. is still positive, as indicated by the shaded area ABC.

The illustration serves as a framework for the empirical analysis of the costs and benefits to the United States from agricultural technology transfer. The 1985 field crop budgets for the states of Sonora and Sinaloa are used as a secondary data source. These were constructed for four representative irrigation districts, two in each state (Sartorio), and were based on budgets prepared by credit institutions and by farmers' organizations. Yields were obtained from statistical data reported by the respective irrigation districts. The crop budgets include corn, beans, sorghum, soybean, safflower, sesame, tomato, green pepper, cotton, chick-peas, and alfalfa in Sonora. All of these crops, plus rice and potatoes, and excluding alfalfa, were available for Sinaloa.

The crop mix and surface harvested in irrigated agriculture in Sonora and Sinaloa are shown in Table 5-1. Machinery and material input requirements of each crop are different in these four selected districts. Weighted averages are used to determine the input requirements per hectare for each crop(see Table 5-2). These measures are multiplied by the total harvested area of each crop to derive the aggregate input requirements. Machinery requirements are aggregated by hours(see Table 5-3), and then divided by estimates of useful

Table 5-1 Crops and Harvested Area in Irrigated Agriculture, Sonora & Sinaloa
(Average Has. 1980-1984)

CROPS	SONORA	SINALOA
Corn	33,714	26,737
Wheat	304,581	147,844
Beans	8,652	72,229
Sorghum	11,405	69,209
Rice	---	43,870
Soybeans	95,863	166,823
Safflower	36,608	94,949
Seasame	25, 515	4,560
Tomatoes	26,662	20,416
Green Peppers	4,642	6,171
Potatoes	----	5,209
Cotton	82,246	22,871
Chick-peas	17,165	11,279
Grapes	23,219	---
Alfalfa	18,889	---
Sugarane	---	40,301
Other Crops	46,930	43,573
TOTAL	708,868	778,762

Source: Avalos, Beatriz: Competitiveness, Efficiency and Policy in Modern Irrigated Agriculture in the States of Sonora and Sinaloa, Mexico. Master Degree Thesis, The University of Arizona, Tucson, AZ. 1987

Table 5-2 Machinery & Material Input Reqirements For Selected Crops, Sonora & Sinaloa (Hours/Ha.)

SONORA	Tractor 150HP	Tractor 80HP	Disk Plow	Disk Harrow	Fertilizer Sp.	Subsoiler	Grain Drill
Corn	7.5	7.5	2.5	3	0.75	--	1
Beans	7.7	4.05	2.5	2.83	0.75	--	1
Sorghum	6.9	6.34	2.5	2	0.75	--	1
Soybeans	7	5.75	2.5	2	0.75	--	1
Safflower	7.86	4.75	2.5	2.83	0.75	--	1
Sesame	6.5	4.92	2.5	2	0.75	--	1
Tomatoes	12.25	11.75	2.5	4	3.75	3.5	--
Green Peppers	12.25	9.25	2.5	4	2.25	3.5	--
Cotton	7.58	11.74	2.5	2.83	0.75	--	1
Chick-peas	6.5	3.75	2.5	2	0.75	--	1
Alfalfa	1.39	9.94	0.36	0.29	0.58	0.5	--
SINALOA							
Corn	6.5	6.25	2.5	2	0.75	--	1
Rice	6.25	1	2.5	2	--	--	1
Beans	7.46	4.3	2.5	2.45	0.75	--	1
Sorghum	8.5	3.75	2.5	3	0.75	--	1
Soybeans	9	4.75	2.5	3	0.75	--	1
Safflower	7.45	4.2	2.5	2.45	0.75	--	1
Seasame	8	4.5	2.5	3	0.75	--	1
Tomatoes	14	15.25	2.5	3	0.75	3.5	--
Green Peppers	14.5	11.75	2.5	3	0.75	3.5	--
Potatoes	9	6	2.5	3	0.75	--	--
Cotton	6.75	9	2.5	2	1.5	--	1
Chick-peas	6.75	3.75	2.5	2	0.75	--	1

Table 5-2 Continued

SONORA	Hiller & Ditcher	Furrowing Ep.	Vertical Cult	Land Plane	Fertilizer (MT)	Seeds (Kg)
Corn	1	1	2	--	.56	20
Beans	1	1	1.17	--	.11	60
Sorghum	1	1	2.09	--	.72	15
Soybeans	1	1	3	--	.4	100
Safflower	1	1	2	--	.57	16.7
Sesame	1	1	2.17	--	.29	2.9
Tomatoes	1	4	4	.75	1	16500 pt
Green Peppers	1	4	3	.75	.75	16500 pt
Cotton	1	1	6	.75	.61	43.3
Chick-peas	1	1	1	--	.29	90
Alfalfa	.21	--	--	.11	.15	3.57
SINALOA						
Corn	1	1	2	--	.44	20
Rice	1	--	--	.75	.4	140
Beans	1	1	1.55	--	.27	95.5
Sorghum	1.5	1	1	--	.2	25
Soybeans	1.5	1	2	--	.18	100
Safflower	1	1	1.45	--	.255	19.1
Sesame	1	1	1	--	.18	4
Tomatoes	2.5	6	4	1.5	1.9	1.03
Green Pepper	1.5	6	5	1.5	1.8	2
Potatoes	1.5	1	2	--	1.5	3000
Cotton	1	1	4	.75	.55	50
Chick-peas	1	1	1	.75	.15	100

Table 5-3 Machinery Input Requirements and Useful Lives

Machinery	Requirements in Sonora & Sinaloa (hr.)	Useful Life (hr.)
Tractor 150 HP.	11,386,867	10,000
Tractor 80 HP.	9,057,961	10,000
Disk Plow	3,634,149	4,500
Disk Harrow	3,728,633	3,500
Fertilizer Sp.	1,117,859	4,500
Subsoiler	206,695	3,500
Grain Drill	1,387,103	3,600
Hiller & Ditcher	1,677,079	3,000
Furrowing	2,620,972	3,000
Vertical Cult	3,542,440	3,600
Land Plane	286,267	4,500

life to get the number of machinery implements required for annual production.

Due to lack of the other crop budgets, such as wheat, grapes and sugarcane, the rest of the harvested surface was assumed have the some average input requirements as those that were calculated. The aggregate input requirements for these two states are summarized in Table 5-4.

1989 Arizona Farm Machinery Costs are used as tractor and implement prices (Daugherty and Wade). The prices for fertilizer and seeds are all from the intermediate input catalogues of Sonora and Sinaloa in 1985. The fertilizer price is an average of different chemical fertilizer, since crop budgets do not distinguish between different kind of fertilizers. Pesticide inputs are ignored because of problems with unit and variety differences. In addition, the U.S. economy also realized direct gains from the provision of marketing and transportation services, managerial consulting, and financial services. Because of lack of data, these gains could not be estimated.

Agricultural inputs demand in these two states is supplied by both domestic production and imports. Assumptions have to be made to determine how much is imported from the United States. Based on prior study, 35% of machinery inputs are assumed to be imported from the U.S. and 65% are produced domestically. For these domestic products, 40% of the materials are imported and 60% are domestic. In order to

Table 5-4 Total Machinery & Material Input Requirements, Sonora & Sinaloa, 1985

	Quantity	Unit Price (dollar)	Value (million $)
Tractor 150HP	1,139	56,682	64.56
Tractor 80HP	906	28,675	25.98
Disk Plow	808	8,702	7.03
Disk Harrow	1,065	1,242	1.32
Fertilizer Sp.	248	7,463	1.85
Subsoiler	59	7,747	0.46
Grain Drill	385	7,441	2.86
Hiller&Ditcher	559	895	0.50
Furrowing Eq.	874	1,999	1.75
Vertical Cult	984	4,226	4.16
Land Plane	64	11,988	0.77
Fertilizer(MT)	725,392	365	265.01
Seeds(MT)	107,929	varies	67.33

facilitate the economic surplus calculation, all machinery and implements are grouped into one category. According to the Fertilizer Yearbook, 17.5% of fertilizer consumed in Mexico was imported. Seeds are assumed to have the same importation percentage as machinery.

The imported value of agricultural inputs from the U.S. in 1985 is derived by applying the percentage to the total requirement in Sonora and Sinaloa. These two states imported about 68 million dollars of agricultural machinery and implements, 41 million dollars of improved seeds and 46 million dollars worth of fertilizers from U.S. producers. Total U.S. domestic farm input expenditure was obtained from USDA Agricultural Resources-Inputs Situation and Outlook. In 1985, U.S. domestic farm expenditure was 5,590 million dollars on machinery and 3,170 million dollars on seeds. 49.1 million tons of fertilizer were consumed. Supply and demand elasticities for farm production inputs are presented in Table 5-5.

A price index approach is used to calculate the changeof producer surplus and consumer surplus, because the machinery and export data are available only in value terms. Let the current price be 1, the price and the quantity without the Mexican technology-induced demand be P*. The elasticities of demand and supply can then be represented as follows:

$$E \text{ supply} = (5658-Q^*)P^*/(1-P^*)Q^* = 0.275$$

$$E \text{ demand} = (Q^*-5590)P^*/(1-P^*)Q^* = 1.5$$

Table 5-5 Agricultural Machinery and Material Inputs, U.S. Consumption and Exports to Northwest Mexico

	Machinery & Implemet (million $)	Seeds (million $)	Fertilizer (million Ton)
U.S. Demand (a)	5590	3170	49.1
Sonora & Sinaloa Inoirted Ag-input	68	41	0.13
Input Supply Elasticity (b)	0.275	0.18	0.144
Input Demand Elasticity (c)	1.5	1.5	1.8

Sources: (a) "Agricultural Resources--Inputs Situation and Outlook" 1986, 1989

(b)&(c) Luther Tweeten, "Foundations of Farm Policy" University of Nebraska Press, 1970 rearranging terms gives equations (1) and (2):

(1) $Q^*(1-P^*) = P^*(5658-Q^*)/0.275$

(2) $Q^*(1-P^*) = P^*(Q^*-5590)/1.5$

applying the market equilibrium condition in which demand equals supply, gives the following solution for Q*:

$$P^*(5658-Q^*)/0.275 = P^*(Q^*-5590)/1.5$$

$$(5658-Q^*)/0.275 = (Q^*-5590)/1.5$$

$$8487 - 1.5Q^* = 0.275Q^* - 1537.25$$

$$Q^* = 5647.46$$

from (2):

$$Q^*-Q^*P^* = (Q^*P^* - 5590P^*)/1.5$$

$$1.5Q^* - 1.5Q^*P^* = Q^*P^* - 5590P^*$$

$$P^*(Q^* -5590 +1.5Q^*) = 1.5Q^*$$

$$P^* = 1.5Q^*/(Q^* - 5590 + 1.5Q^*)$$

$$= 8471.19/(5647.46 - 5590 + 8471.19)$$

$$P^* = 0.99$$

now, the change of producer surplus from machinery export to Sonora and Sinaloa, which is indicated by area P*P0BC in Figure 5-1, can be calculated as:

$$Q^*(P0-P^*) + (5658-Q^*)(P0-P^*)/2$$

$$= (5647.46)(0.01) + (5658-5647.46)(0.01)/2$$

$$= 56.5273 \text{ (million dollars)}$$

and the U.S. net social benefit, which is indicated by area ABC in Figure 5-1, can be calculated as:

$$\text{Net Social Benefit} = (68)(0.01)/2$$

$$= 340 \text{ (thousand dollars)}$$

Using the same approach, the change of producer surplus and the net social benefit from seed exports is calculated as 32 million dollars and 205 thousand dollars, respectively. The producer and the U.S. net social benefits from fertilizer exports are 24 million dollars and 32 thousand dollars, respectively.

In summary, the total producer surplus change from the farm input exports to Northwest Mexico is 112 million dollars. Deducting the domestic consumers' loss, the United States as a donor country still gains net benefits of about 577 thousand dollars.

5.3 Cost and Benefit to U.S. Winter Vegetable Producers and Consumers

The United States imports over 16 different kinds of winter vegetables from Mexico, but the major fresh ones are tomatoes, cucumbers, peppers, squash, and eggplant. Florida and Sinaloa have been the principal suppliers of winter fresh vegetables to the U.S. market since the end of the 1960's.

Before the early 1960's, U.S. demand for fresh winter vegetables was met domestically by Florida and California, supplemented with imports from Cuba and Mexico. In 1962, after a few years of increasing tension, all U.S. trade with Cuba was embargoed. Two years later, the United States terminated the Bracero program with Mexico, under which Mexican workers provided a low-wage labor supply for U.S. agriculture. The scarcity of cheap labor convinced California tomato growers to abandon the risky winter production in favor of less labor-intensive crops. By 1966, therefore, Florida and Mexico were left to split the market between themselves.

However, Florida's winter-vegetable growers were suffering from increased costs of production. High labor costs, increasing land costs due to real estate development, and weather problems caused the state's production of winter vegetables to stagnate or decline throughout the 1968-1973 period(see Table 5-6). As the only other source during the winter season, Mexico gained dramatically from Florida's inability to meet the ever-increasing demand. Imports from Mexico dominated the Western markets and began to make inroads into Eastern ones. After 1974, this trend started to reverse. Mexican growers began to suffer from rising costs, particularly for labor and an overvalued currency. Florida producers became more competitive because of mechanization and better farming practices.

Winter vegetable production in Sinaloa benefitted substantially from U.S. agricultural technology transfer, especially because of the import of improved seeds and irrigation system. The competition between Florida and Mexico increased fresh winter vegetable availability in the U.S.

Table 5-6 U.S. Winter-Vegetable Production, Florida and Mexico (1962-1982)
(Tomatoes in thousands of 30 cartons; other vegetables in bushels)

	Tomatoes		Cucumbers		Bell peppers		Squash		Eggplant	
Season	Florida	Mexico	Florida	Mexico	Florida	Mexico	Florida	Mexico	Florida	Mexico
1962/63	20,617	9,807	3,405	266	4,071	480	1,052	25	800	104
1963/64	22,395	9,929	3,751	282	4,401	369	924	42	850	95
1964/65	22,131	10,690	3,699	572	4,345	567	988	108	953	137
1965/66	21,510	13,052	3,669	762	4,475	807	992	104	906	173
1966/67	22,401	14,028	3,469	1,211	5,171	885	984	239	966	202
1967/68	21,248	13,123	3,696	978	5,593	772	1,158	156	724	270
1968/69	17,706	17,790	2,778	1,897	5,030	1,318	1,093	386	731	502
1969/70	13,139	23,152	2,784	2,344	2,914	2,202	808	547	532	711
1970/71	16,515	20,706	2,442	3,446	3,821	3,928	943	532	708	735
1971/72	18,697	20,699	3,231	2,988	4,800	3,160	1,041	608	794	871
1972/73	18,798	26,228	3,130	3,244	5,716	3,835	1,126	617	763	1,218
1973/74	19,676	21,125	2,916	3,289	5,521	4,402	1,124	683	896	1,044
1974/75	23,349	18,707	3,645	2,052	7,007	2,790	1,427	608	1,203	835
1975/76	24,380	21,125	4,061	3,404	6,320	2,997	1,406	800	1,191	994
1976/77	20,737	25,302	3,970	3,910	6,279	3,792	1,700	996	1,224	1,037
1977/78	24,180	31,026	4,018	4,632	7,976	5,956	1,536	1,459	1,291	1,289
1978/79	28,990	22,765	4,226	4,718	7,188	5,213	1,810	2,353	1,294	1,215
1979/80	38,705	15,488								
1980/81	38,655	6,523								
1981/82	42,151	15,691								

Source: Johnston, Bruce: U.S.--Mexico Relations: Agricultural And Rural Development
Stanford University Press, 1987

market and allowed lower prices. Earlier studies (Bohall, Vansickle and Alvarado) found that all other things being qual, Florida weekly tomato prices tended to fall as Mexican hipments rose. U.S. consumers got benefits from the winter vegetable imports, but Florida producers lost their dominant influence on the market price.

The calculation of the change in consumer's surplus and producer's surplus gives some insights into the net gain or loss for the U.S. Tomatoes are the most important fresh winter vegetable imported from Mexico, accounting for about 50% of total winter vegetable imports since 1976. For simplicity and short of other winter vegetable data, the net surplus change from the tomato imports is doubled to approximate the total surplus change from all winter vegetable imports.

Figure 5-2 illustrates the market effects of tomatoes imported from Mexico. The United States imported 368,888 metric tons of fresh tomatoes from Mexico in 1985, while Florida supplied about 500,200 metric tons for the domestic market. The U.S. retail price of fresh tomatoes has been increasing since the 1970's (see Table 5-7). The average price from 1981 to 1989 is used as the base price for the calculations of consumer's surplus and the net social gain. Vegetable supply and demand elasticities are used to deduce the quantity and price for the U.S. market without the importation. Table 5-8 summarizes these data.

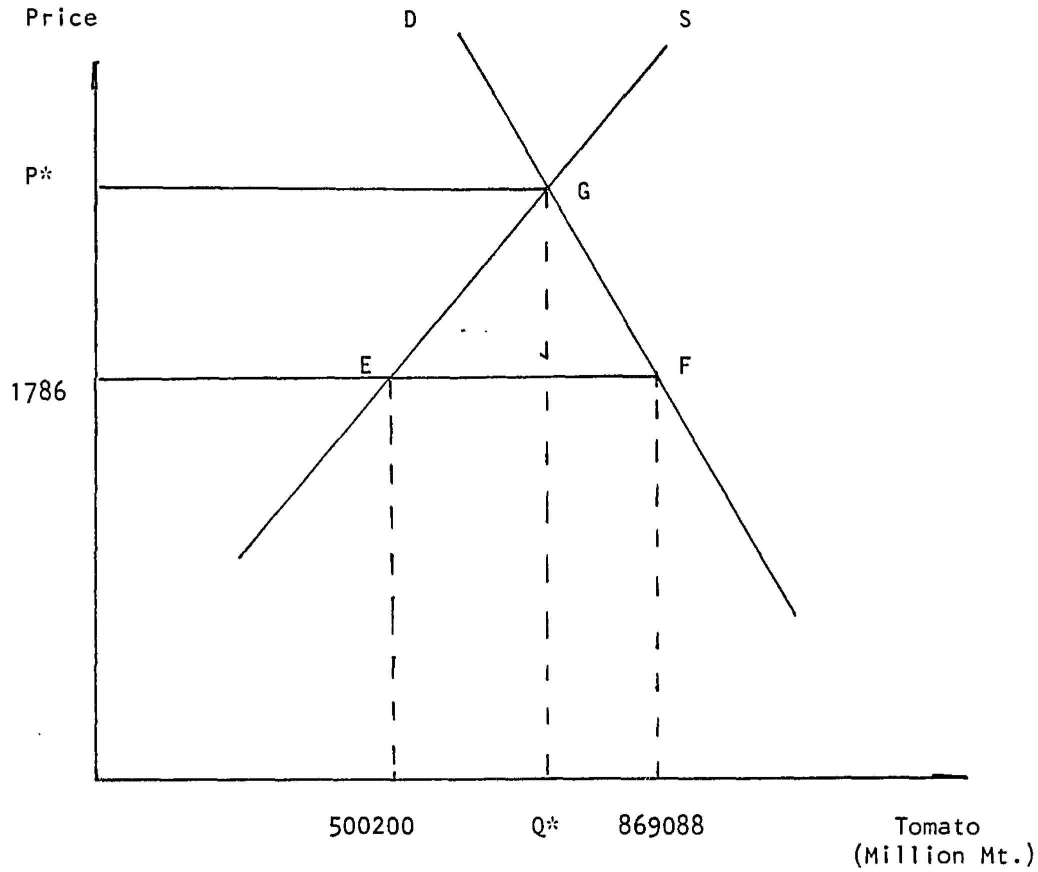


Figure 5-2

The Effect of Tomato Imports on Net Social Benefits is Indicated by Area EFG

Table 5-7 U.S. retail Prices of Fresh Tomatoes

1970-1989

Year	Tomato price (cents/pound)
1970	42.0
1971	46.6
1972	47.0
1973	48.2
1974	54.8
1975	57.8
1976	57.8
1977	67.8
1978	69.5
1979	----
1980	67.4
1981	77.0
1982	73.9
1983	79.1
1984	80.7
1985	77.8
1986	82.4
1987	82.3
1988	83.4
1989	92.5

---- = Not available

Source: Bureau of Labor Statistics, Department of Labor

Table 5-8 Data for the Calculation of Net Social Benefits from Tomato Imports

Florida supply (MT) 1985 (a)	imported from Mexico(MT) (b)	demand elasticity (c)	supply elasticity (d)	price ($/MT)
500,200	368,888	-0.7	0.4	1786

Sources: (a) Agricultural Statistics, USDA, 1986

(b) Foreign Agricultural Trade of the U.S. USDA

(c) William Tomek & K.L. Robinson: Agricultural product Price, Cornell University Press, 1981

(d) Luther Tweeten: Foundations of Form Policy, University of Nebraska Press, 1970

Let the tomato quantity and price in the U.S. market without the importation from Mexico be Q* and P*, respectively. The elasticities of tomatoes demand and supply can be represented as follows:

E supply = (Q*-500200)P*/(P*-1786)Q* = 0.4

E demand = (869088-Q*)P*/(P*-1786)Q* = 0.7

rearranging terms gives equations (1) and (2):

(1) Q*(P*-1786) = P*(Q*-500200)/0.4

(2) Q*(P*-1786) = P*(869088-Q*)/0.7

Applying the market equilibrium condition (demand equals supply) gives the following solution for Q*:

P*(Q*-500200)/0.4 = P*(869088-Q*)/0.7

0.7(Q*-500200) = 0.4(869088-Q*)

Q* = 634,341 (million MT)

Bringing Q* into (2):

0.7Q*(P*-1786) = P*(869088-Q*)

444038P*-792926250 = 869088P*-634341P*

P* = 3788 (dollar/MT.)

Therefore, the change of U.S. consumer's surplus from the tomato imports can be estimated as:

Q*(P*-1786) + 234747(P*-1786)/2

=(634341)(2002) + (2002)(234747)/2

= 1,504,932,450 (dollars)

And the U.S. net social benefit is:

(368888)(2002)/2 = 369,256,888 (dollars)

The total U.S. consumer's benefit and the net social gain from all winter vegetable imports are estimated by doubling these figures, yielding estimates of 3010 million dollars and 738 million dollars respectively.

Because demand and supply elasticities are not known with confidence, a sensitivity analysis is necessary. Table 5-9 gives the result, which shows that a small change in elasticities can cause a big change in consumer surplus and net social benefit.

5.4 Conclusion

This empirical analysis shows that the U.S.-Northwest Mexico agricultural technology transfer gives benefits to both countries. Northwest Mexico has experienced significant growth in farm production and established a modern agriculture. Sonora and Sinaloa become the major agricultural producers for domestic consumption as well as exportation. The U.S. consumers and farm input producers both got benefits. In 1985, the winter vegetable importation gave U.S. consumers over 3010 million dollars in benefits, and the farm inputs export gave U.S. producers over 112 million dollars of benefits. These gains are partially offset by losses to the Florida vegetable producers and to the farm input consumers, leaving a net social benefit to the U.S. of around 739 million dollars. If the benefits are projected into the future, the present worth

Table 5-9 Sensitivity Analysis of Tomato Supply Elasticity and Demand Elasticity

		Demand Elasticity			
		-0.5	-0.7	-1.0	-1.5
Supply Elasticity	0.2	8828 a/ 2208 b/	3083 784	1545 398	838 219
	0.4	2207 531	1506 369	1015 254	654 167
	1.0	709 162	615 143	512 122	400 97
	1.5	458 103	416 95	365 85	304 72

Note: a/ Change of Consumer Surplus. (Million $)
b/ Net Social Benefit. (Million $)

of the stream of benefits discounted at 5% is 5.7 billion dollars over a ten year period and 9.2 billion dollars over twenty years.

The consumer benefits in this analysis may be a very special case, since the United States and Mexico are neighbors. The trade between these two countries has a relatively low transportation cost. However, a global benefit to consumers still exists whether or not the donor and recipient countries are adjacent, because technology transfer increases production efficiency and makes the world price go down. All consumers in the world will benefit from this change.

CHAPTER 6

CONCLUSIONS

Technological change is required for agricultural development. The gap that exists between the technologies in developed and less developed countries leads to the possibility and necessity of technology transfer. In order to maximize their benefits from new technology, less developed countries must perform local research to adapt the technology to their local needs and to ensure that benefits are distributed in an equitable manner.

This thesis has focused on the effects of technology transfer on the donor country. Conventional arguments consider only whether technology transfer to less developed countries will be against the donor country's interest in agricultural product exports. It is incomplete because the effect on the donor country's consumers are omitted. This paper has applied the economic surplus concept to discuss both the producer and consumer affects associated with technology transfer.

An empirical analysis of the U.S.-Mexico agricultural technology transfer has been presented. The results show that both Mexico and the United States benefitted from technology transfer. Northwest Mexico has experienced substantial growth in agricultural production over the past three decades. The transferred agricultural technology has changed this area from one of traditional agriculture into a modern agricultural sector. The United States has benefitted from exportation of new agricultural technology, as well as the importation of winter vegetables from Northwest Mexico.

Transferred technology helped speed up agricultural development in Mexico and increased incomes in the agricultural sector. The income increases undoubtedly caused increases in food demand, stimulating imports. U.S. food exports to Mexico have grown rapidly since 1970, but it is unclear how much of the income growth and exports are due to technology transfer. Thus, it is hard to estimate the benefits to U.S. food exporters. Additional research work needs to be done to quantify the links of technology transfer to income growth, food demand, and food imports.

LIST OF REFERENCES

Anderson, Kym (1989) Does Agricultural Growth in Poor Countries Harm Agricultural-Exporting Rich Countries? In: Agricultural Economics 3, 1989 PP.309-321

Avalos, Beatriz (1987) Competitiveness, Efficiency and Policy in Modern Irrigated Agriculture in the States of Sonora and Sinaloa, Mexico. Master's Degree Thesis, the University of Arizona, Tucson, AZ.

Beckford, George (1984) Induced Innovation Model of Agricultural Development: Comment. In: Eicher, Carl and Staatz, John Agricultural Development in the Third World. (Baltimore: the Johns Hopkins University Press). PP.75-81

Cassio, Luiselli (1985) The Route to Food Self-Sufficiency in Mexico--Interactions with the U.S. Food System. Monograph series 17, Center for U.S.-Mexican Studies, the University of California, San Diego.

Cline, William (1975) Distribution and Development--A Survey of Literature. In: Journal of Development Economics 1, Feb. 1975, PP.359-400

Daugherty, Lew and Wade, James (1989) 1989 Arizona Farm Machinery Cost. Cooperative Extension Service, Department of Agricultural Economics, the University of Arizona, Tucson, AZ.

Eckaus, Richard (1977) Appropriate Technology for Developing Countries. National Research Council, Washington, D.C.

Food and Agriculture Organization (1985) Fertilizer Yearbook, Rome.

Ghatak, Subrata and Ingersent, Ken (1984) Agriculture and Economic Development. (Oxford: The Harvester Press Publishing Group)

Gittinger, J. Price (1982) Economic Analysis of Agricultural Projects. (Baltimore: The Johns Hopkins University Press)

lIST OF REFERENCE-- CONTINUED

Grabowski, Richard (1981) Induced Innovation, Green Revolution, and Income Distribution--Reply. In: Economic Development and Cultural Change, Vol. 30, Oct. 1981. PP.177-182

Hayami, Yujiro (1981) Induced Innovation, Green Revolution, and Income Destribution: Comment. In: Economic Development and Cultural Change, Vol.30. October 1981. PP.169-176.

Hayami, Yujiro and Ruttan, Vernon (1985) Agricultural Development--An International Perspective. (Baltimore: the Johns Hopkins University Press)

Hetzler, Stanley (1969) Technological Growth and Social Change--Achieving Modernization (London: Routlege & Kegan Paul)

Jackson, Sarah (1972) Economically Appropriate Technologies for Developing Countries--A survey. Occasional Paper 3, Overseas Development Council, Washington, D.C.

Janvry, Alain de and Sadoulet, Elisabeth (1988) The Conditions for Compatibility between Aid and Trade in Agriculture. In: Economic Development and Cultural Change. Vol.37, October 1988. PP.1-32

Johnston, Bruce (1987) U.S.-Mexico Relations--Agricultural and Rural Development. (Stanford: Stanford University Press)

Johnston, B. and Kilby, P. (1975) Agriculture and Structural Transformation. (New York: Oxford University Press,

Just, Richard & Hueth, Darrell & Schmitz, Andrew (1982) Applied Welfare Economics and Public Policy. (Englewood Cliffs: Prentice-Hall, Inc.)

Kuznets, Simon (1955) Economic Growth and Income Inequality. In: the American Economic Review. Vol.45, Mar. 1955. PP.1-28

LIST OF REFERENCES--CONTINUED

Nelson, Richard (1974) Less Developed Countries--Technology Transfer and Adaptation: The Role of the Indigenous Science community. In: Economic Development and Cultural Change Vol.23, October 1974. PP.61-78

Pearce, D.W. (1983) Cost-Benefit Analysis. (London: MacMillan)

Pearse, Andrew (1980) Seeds of Plenty, Seeds of Want: Social and Economic Implications of the Green Revolution. (Oxford: Clarendon Press).

Prasad, A.J. (1981) Technology Transfer to Developing Countries through Multinational Corporations. In: Hawkins, Robert and Prasad, A.J. Research in International Business and Finance, Vol.2, 1981. (Greenwich: Jai Press Inc.)

Rosegger, Gerhard (1986) The Economics of Production and Innovation. (Oxford: Pergamon Press)

Rosenberg, Nathan (1982) Inside the Black Box--Technology and Economics. (Cambridge: Cambridge University Press)

Rosenberg, Nathan (1976) Perspectives on Technology. (Cambridge: Cambridge University Press)

Sidhu, Surjit (1974) Relative Efficiency in Wheat Production in the Indian Punjab. In: The American Economic Review, Vol.64. Sep. 1974. PP.742-751

Staatz, John & Eicher, Carl (1984) Agricultural Development Ideas in Historical Perspectives. In: Staatz, John and Eicher, Carl Agricultural Development in the Third World. (Baltimore: the Johns Hopkins University Press). PP.3-23

Stewart, Frances (1979) International Technology Transfer--Issues and Policy Option. World Band Staff Working Paper. No. 344. Washington, D.C.

Stopford, John & Wells, Louis (1972) Managing the Multinational Enterprise. (New York: Basic Books)

LIST OF REFERENCES--CONTINUED

Teece, David (1981) Technology Transfer and R&D Activities of Multinational Firms: Some Theory and Evidence. In: Hawkins, Robert and Prasad, A.J. <u>Research in International Business and Finance</u>. Vol.2. 1981 (Greenwich: Jai Press Inc.)

Tomek, William & Robinson, Kenneth (1981) <u>Agricultural Product Prices</u>. (New York: Cornell University Press)

Tweeten, Luther (1970) <u>Foundations of Farm Policy</u>. (Lincoln: University of Nebraska Press)

World Bank (1987) <u>World Development Report</u>. (New York: Oxford University Press)