AID POLICY PAPER

TECHNOLOGY GENERATION, DIFFUSION,

AND ACQUISITION

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"... we should be a leader among all the donors in using science and technology as the most basic vehicle for change. That our business is the creation and transfer of productive ideas should permeate each of our projects, in every sector and every region."

-- M. Peter McPherson

INTRODUCTION

Transferring improved technologies is one of the most potent means available to AID for achieving its primary objective: promoting sustained, broadly based economic growth. It is, however, very difficult to measure -- let alone to stimulate -- the transfer of technology. Differences in estimates of labor productivity do offer crude indicators of the degree to which improved technologies have been incorporated into nations' economic systems. 1/ These estimates indicate that labor is, on average, about ten times more productive in developed countries than it is in developing countries. So measured, the "technological gap" is greatest by far in agriculture (see Table 1).

1/ Differences in labor productivity are not solely attributable to differences in the degree to which more productive technologies are adopted. Furthermore, technological change increases the productivity of the combination of all inputs, not just labor inputs. However, for our purposes, an increase in the productivity of labor is a useful indicator of the "technological gap" that exists between nations. Other indicators include the very small (about 3.0 percent) share of GNP spent by developing countries on research and development, the limited number (about 1 per 10,000 persons) of scientists and engineers engaged in research and development in developing countries, and the very few (6 percent of world's total, of which 84 percent are held by foreigners) existing patents granted by developing countries. See UNCTAD Secretariat, Planning for the Technological Transformation of Developing Countries (NY: United Nations) 1981, p. 59.

Table 1: GDP by Sector, per Head of Economically Active Population, 1975

Sector	Developed Countries (US$) (1)	Developing Countries (US$) (2)	Ratio (1)/(2) (3)
Agriculture	5,190	430	12.2
Industry	14,230	2,370	6.0
Mining	17,810	9,220	1.9
Manufacturing	13,640	1,870	7.3
Consumer Goods 1/	10,600	1,290	8.2
Intermediate Goods 2/	18,720	3,250	5.8
Capital Goods 3/	14,960	3,070	4.9
Electricity, Gas and Water	36,430	7,270	5.0
Services plus Construction, Transport and Comunications	12,610	2,650	4.8
Total	12,290	1,230	10.0

1/ ISIC Divisions 31, 32, 33, 34, and 39.
2/ ISIC Divisions 35 and 36.
3/ ISIC Divisions 37 and 38.

Source: UNCTAD Secretariat, Planning the Technological Transformation of Developing Countries, (NY: United Nations) 1981, p. 20

Bridging the technological gap means increasing, in a sustainable manner, the productivity of labor. But long term efforts to increase the productivity of labor often collide with short term concerns about technologically induced unemployment. 2/ This is the "fundamental dilemma" of technology transfer: in the long run, raising average labor productivity increases total output; in the short run some people may be made worse off than before. While the introduction of improved technologies will increase the abysmally low productivity of labor in developing countries it must not be allowed to exacerbate the alarmingly high levels of unemployment and underemployment of labor also characteristic of these countries. Confronting this fundamental dilemma in a forthright and sensitive manner is the key to "using science and technology as the most basic vehicle for change."

As little as a decade or two ago, experts argued that developing countries easily could take advantage of the technological experiences of the industrialized countries. The existing "shelf of technologies" contained equipment and expertise from which developing countries merely needed to choose. It was widely assumed that developing countries could leapfrog historical evolution by attaining economic take-off in a fraction of the time that Western nations had required and at a fraction of the expense

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2/ See AID's forthcoming policy paper on employment.

involved. The world was confident that technologies needed for development were readily available, perhaps with minor modifications, and that the major problems of technology policy involved establishing a broad infrastructure to support scientific research. Adaptation and productive use of imported technologies were presumed to follow automatically. This presumption has proven false.

History is filled with examples of inventions best exploited by nations that did not generate those inventions. As is well known, three key inventions, viz. moveable type, gun powder, and the compass, contributed dramatically to the development of Europe. Europeans fully exploited these three inventions; none, however, originated in Europe. The capacity to acquire new technologies whatever their origins is an important part of the development process.

However, this capacity is not easily built. The extensive academic literature on the choice of technology identifies a number of complicating factors including distorted price signals, poor information flows, and otherwise imperfect markets. Furthermore, since these "already available" technologies reflect the factor scarcities of the industrialized countries in which they originate, they may not be easily adapted for use in developing countries.

Clearly, the adaptability of any particular technology depends heavily on the social, institutional and physical systems on which it is imposed and with which it interacts. 3/ AID pays special attention to the adaptation of existing technologies that appear likely to have a powerful positive impact on development. The importance of continual technological adaptation cannot be overstated. While the assimilation of a technology newly imported from abroad is a major technological change, case study research demonstrates that the subsequent, gradual improvement in the productivity with which the technology is used is the source of technological mastery. 4/ It is clear that technology transfer by itself does not necessarily lead to technological mastery. Without technological mastery, the entire technology transfer process remains incomplete.

3/ Some technologies overwhelm local cultures. The introduction of steel axes in a stone age Australian society led to cultural changes that virtually destroyed that society. See Sharp, Lauriston, "Steel Axes for Stone Age Australians", in Spicer, Edward H. (ed.) Human Problems in Technological Change (NY: Russel Sage Foundation) 1952. Some cultures overwhelm seemingly valuable technologies. The effort to sell in the U.S. an analgesic-antacid pill that "works without water" failed because headache sufferers in this culture unconsciously associate water with a cure; they "... had no confidence in a tablet that dissolved in the mouth." See Rogers, Everett M., Diffusion of Innovations (NY: Free Press) 1962, p. 123, adapted from Schorr, "The Mistakes: Many New Products Fail Despite Careful Planning, Publicity", Wall Street Journal, 5 April 1961, pp. 1, 22.

4/ See Dahlman, Carl J. and Larry Westphal, "The Meaning of Technological Mastery in Relation to Transfer of Technology," Annals of the American Academy of Political and Social Science, 458, 1981, pp. 17-18.

The Definition of Technology

For the purposes of this paper, "technology" is defined as a body of knowledge about techniques. "Techniques" are methods of producing goods and services. An "improved technique" involves a change in the quality or quantity of the inputs actually used in production, a change in the means of organizing those inputs, or a change in the nature of goods and services produced.

The word "technology" embraces software as well as hardware. "Technology" is embodied in equipment and expertise. The equipment includes vehicles, machinery, buildings, and the process technologies incorporated in intermediate goods. For example, sugar mill owners may increase their profits by adopting improved cane crushing machinery. The expertise includes management skills, knowledge of production processes, and organizational knowhow. For example, farmers may increase their marketable surplusses by changing only their ploughing patterns.

The word "technology" also conjures up images of large, "technology intensive" manfacturing industries such as steel and petrochemicals, or of "hightech" firms such as those in the computer and biogentic engineering businesses. But the critical problems in developing countries cry out for the application of technologies suitable for small scale farmers, small scale industrial entrepreneurs, petty traders, and poor people generally.

The technology transfer process must be viewed in systemic terms if it is to be understood. The technology transfer process is complex. In agriculture, for example, it embraces research professionals, extension agents, and farmers. In more abstract terms, it embraces the generation, diffusion, and acquisition of technology. These three components of the technology transfer process define the analytical framework of this policy paper. This framework is discussed in detail in Section III, below.

The Importance of Policy

Administratively determined prices distort markets for technology just as they distort all other markets. An overvalued domestic currency encourages producers to import technology rather than to use local technology. Artificially high wage rates encourage producers to adopt socially inefficient, capital intensive production techniques. Artifically scarce working capital limits the technological options available to producers. Restrictions on competitive economic behavior dull the development of entrepreneurial skills and the attendant continuing search for new technologies that increase productivity and enhance product quality.

Examples abound. China promoted woefully inefficient back yard blast furnaces as part of the Great Leap Forward. Modern plants operate at a small fraction of their capacities in a number of developing countries. Entrepreneurs operate lucrative

local monopolies behind protective tariff barriers. Rusting hulks of imported earth moving machinery dot the landscape in many developing countries as mute reminders of the ways that "cheap" foreign exchange usually is misused. In many countries, efforts to encourage local manufactures by restricting competition result in sellers' markets in which the incentives to use labor (abundant and inexpensive) rather than capital (scarce and expensive) are weakened.

Although these problems all appear to be technological problems, they are in fact more deeply rooted in policy decisions.

> The 15 years since the United Nations Conference on Science, Technology, and Development in Geneva have taught us that what seemed at first to be technological obstacles to development frequently turn out on closer examination to have been policy failures. 5/

Having identified what appears to be a technological problem, AID must first pursue the possibility that the technological problem is but a symptom and that the policy framework is the diseas Only after having thoroughly explored the policy framework will AID engage in activities linked to specific issues in technology transfer.

5/ Weiss, Charles Jr., "Mobilizing Technology for Developing Countries," Science, 203, 1979, p. 1083.

THE POLICY FRAMEWORK

AID policy must be consonant with overall U.S. government policy. This section presents a brief summary of that policy and provides the framework for AID's technology transfer policies.

Putative measures of the outward flow of technology from the U.S. all tell a similar story: technology flows from the U.S. to AID recipient countries are small compared to overall technology flows from the U.S. 6/ For example, one measure of U.S. technology flows is "fees and royalties received from foreigners." In 1981, flows allocated by geographic areas were $7,521 million. 7/ Of this amount, only $1,590 million in fees and royalties originated in Asia, Africa, and Latin America. The vast majority of this share originated in non-AID recipient countries (e.g., Mexico, Brazil, Venezuela, Argentina, Singapore, South Korea).

Another measure is "plans for expenditures by majority owned foreign affiliates (MOFAs) of U.S. companies." In 1983, plans for capital expenditures of MOFAs in technology intensive

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6/ These "putative measures" include, inter alia: fees and royalties received from foreigners; overseas capital expenditures by U.S. companies in technology intensive industries; the value of education and training provided to foreigners in the U.S.; and exports of machinery and equipment from the U.S.

7/ U.S. Government, Department of Commerce, Survey of Current Business, 1983, 62, 9, pp. 64-69. The negative flows to "International Organizations and Unallocated" have been ignored.

manufacturing industries (basically capital goods, e.g., machinery and transportation equipment) amounted to $10,579 million (about 23% of all planned capital expenditures by MOFAs). Developing countries accounted for only $1,500 million. Again, the vast majority was in non-AID recipient countries; only about three percent of the capital expenditures by MOFAs in technology intensive manufacturing industries are planned to occur in AID recipient countries. 8/

It also may be noted that U.S. exports of goods and services ($105,740 million in 1981) are about fourteen times greater than technology exports measured by "fees and royalties from foreigners". Technology transfer issues normally are raised in the context of debates on trade policies. It is not surprizing that official concerns with technology transfer normally are dominated by concerns with larger trade issues. Furthermore, just as trade issues dominate technology transfer issues, so do technology transfer issues involving non-AID recipient countries dominate technology transfer issues involving AID recipient countries.

The Foreign Policy Context

The multilateral trading system established after World War II increasingly is turning into an extremely complex system based on bilateral agreements. In the U.S., high unemployment

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8/ U.S. Government, Department of Commerce, op. cit., p. 46.

rates spawn a rash of protectionist sentiments; exports are viewed with favor, imports (under the slogan "exporting jobs") with alarm. Severe financial problems make earning foreign exchange doubly important; developing countries in particular want to promote exports and otherwise earn foreign exchange. The move away from the multilateral trading system is best signaled by the proliferation of bilateral "self-restraint" agreements on so-called "sensitive products".

Nonetheless, the cornerstone of U.S. policies on technology transfer continues to be a commitment to the principles of free trade. The result has been a market oriented approach to broad questions of trade with, and therefore of technology transfer to, foreign nations. At the same time, the U.S. government does intervene selectively in trade flows. For example, the U.S. government frequently restricts trade outflows on an ad hoc basis justified on strategic grounds. Usually these restrictions involve goods or services that embody advanced or leading edge technologies, military technologies, and dual use technologies. Typically the restrictions involve trade flows to the Soviet Union or other COMECON countries.

The U.S. government also intervenes by promoting trade flows. Institutions such as OPIC, TDP, EXIM Bank, and the Department of Commerce operate export promotion schemes. These schemes may offer credit (or other services) to U.S. exporters at relatively soft terms, or offer financial guarantees against specified risks of foreign investment.

U.S. government efforts to encourage -- or to discourage -- investment flows tell essentially the same story. The general policy is based on a free market approach. However, in a context of constrained official assistance, the U.S. government is placing additional emphasis on stimulating private investment flows to developing countries. For example, the U.S. government is negotiating bilateral investment treaties with a number of developing countries. These bilateral treaties may cover tendentious points such as the repatriation of capital. They recognize the host government's right to exclude foreign investments from key areas and to expropriate an investor's assets with compensation, and they include language on the arbitration of disputes. By establishing clear guidelines, and thereby reducing uncertainty, the U.S. government encourages U.S. private investment in developing countries.

The Developing Country Context

The developing countries are usefully classified in a number of different ways. The newly industrializing countries (NICs), and those oil exporting developing countries running balance of payments surplusses, generally are interested in obtaining modern industrial technologies. These technologies tend to be proprietary and involve patents on closely held know-how; they often are most efficiently transferred by multinational corporations. Understandably, NICs and oil

exporting developing countries emphasize issues such as transfer price, quality, and product reliability. These issues frequently dominate international discussions of technology transfers to developing countries.

Other developing countries, especially AID recipient countries, are more likely to be interested in new (to them) agricultural technologies. They are likely to be more interested in improving the basic educational skills of, in overcoming fundamental health problems of, and in providing jobs for, their people. However, AID recipient countries are not homogeneous.

Accordingly, AID will follow a "two-tier" technology transfer policy. In the poorer countries, AID will seek to establish and strengthen the indigenous capacity to assess, adapt, and aquire technologies; to improve technology delivery mechanisms (especially market mechanisms); and to upgrade traditional technological practices. Basic skills and education training programs are especially important. These activities will emphasize agriculture and related businesses. In the richer countries, AID will seek to establish links between scientific and technological institutions in the developing country and in the U.S.; to encourage the use of market based technology diffusion systems; and to adapt proven technologies to local conditions. Management training programs are especially important. In both sets of countries, AID will

emphasize the role of commercial markets and will seek to stimulate greater demand for improved technologies.

AID will build on the special strengths of the U.S. as a donor nation. Accordingly, AID will emphasize technology transfer efforts in agriculture and agribusiness. 9/ The entrepreneur, building a small business in industrial or in service fields, based on his or her own ingenuity and in response to profitable opportunities, is as important a part of the U.S. heritage as is the independent farmer. AID also will emphasize this well-known success story and help transform the small businesses in developing countries just as AID has helped transform developing country agriculture.

A.I.D. Policy Context

The Foreign Assistance Act of 1961, as amended, (FAA), establishes the four principal goals of U.S. development policy. The FAA also recognizes the role of technology, and of the technology transfer process, in achieving these four principal goals. The FAA explicitly links the problem solving capacity of technological change to the alleviation of poverty, explicitly defines the key functional areas (small farm agriculture, health, population, education, energy, and so forth) in which AID's support for technology transfer is best concentrated, and explicitly describes the kinds of technologies (small scale,

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9/ See the forthcoming Agency policy determination on Agricultural Technology Transfer.

labor intensive) best suited to the tasks at hand.

Several of AID's new policy papers refer to technology transfer. In the "Private Enterprise Development" policy paper, AID discusses the inappropriate nature of many innovations developed in the industrialized countries, the importance of adapting available technologies to local conditions in the developing countries, and the typically thin capacity in those countries to choose or to adapt technology. In the "Institutional Development" policy paper AID emphasizes the links connecting technology producing institutions and user groups. The market is, of course, such a link. In the "Food and Agricultural Development" policy paper, AID emphasizes support for the identification, transfer and adaptation of existing appropriate technologies and for research into the application of new, improved technologies. In the "Domestic Water and Sanitation" policy paper, AID discusses the importance of selecting and adapting technologies that "fit" into the social and cultural as well as the physical setting. AID pays particular attention to software technologies in water and sanitation projects. In the "Population Assistance" policy paper, AID observes that family planning delivery systems are themselves technologies, 10/ and that the U.S. has led the way in

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10/ This point has general validity. Technology diffusion mechanisms are themselves technologies and are subject to technological change. For example, efforts to build grass roots water user associations may make possible the efficient delivery of irrigation water to small scale farmers.

developing, testing and disseminating those systems as well as the contraceptives they deliver. In the "Basic Education and Technical Training" policy paper, AID discusses radio and other media based training systems that are cost-effective means of attaining specific learning objectives.

AID evaluation documents contain a number of findings relevant to the development of technology transfer policies. The background paper for AID's May 1983 Irrigation Conference concludes that donors can help build the institutional capacity of indigenous organizations to adapt technologies in order to solve local problems that change over time. This kind of institution-building should be fully incorporated into overall project design from the beginning. The program evaluation summary on AID's experience in agricultural research observes that the technologies promoted by AID too often failed to alleviate the particular constraints faced by small farmers and so adoption rates by small farmers are lower than anticipated. The summary also observes that price or production incentives often are inadequate to stimulate the adoption of new and otherwise appropriate technologies. The summary of AID's experience in community water supply strongly emphasizes issues involving technology diffusion including the importance for AID project designers of detailed understanding of the local social, ultural, political and economic factors that influence acquisition. The rural roads evaluation summary also emphasizes the

importance of understanding the local conditions and the importance of a good "fit" between the technologies and the prospective beneficiaries involved in a given project.

The thrust of these and other evaluation reports is clear. Most of AID's technology transfer problems flow from a weak understanding of both the diffusion and the acquisition processes and of the factors that influence those processes. AID must increase its understanding of how these processes work and how AID can most efficiently stimulate the diffusion and acquisition of suitably adapted, productive technologies in developing countries.

COMPONENTS OF THE TECHNOLOGY TRANSFER PROCESS

This section provides AID's analytical framework used for addressing technology transfer issues. There are three components. Briefly summarized, they are:

- The generation of new technology, which includes pure and applied scientific research, engineering, and product development and which results in a technically sound product or process;
- The diffusion of technology, which involves principally the adaptation of a technically sound product or process to fit local cultural, economic, environmental, political and social conditions and which results in the widespread availability of that adapted product or process. Technology diffusion typically is effected

through institutions such as the commercial market or an administrative extension system; and

- The acquisition of technology, which implies that the final user of the technology is an active participant in a self sustaining technology transfer process.

Generating New Technology

The generation of new technology typically proceeds through a series of incremental adjustments in methods, machines, and factor inputs. These adjustments can have substantial effect over an extended period.

The Green Revolution has demonstrated that technical change in agriculture depends on far more than a single breakthrough in, for example, plant breeding. A single breakthrough often signals little more than the establishment of a new, somewhat higher but essentially static plateau of poverty. Only a system that is capable of generating a continuing system of improved technologies can lead to self-sustaining economic growth.

A less well known example of the importance of incremental technical adjustments is the body of work on labor intensive civil works construction methods. The preliminary conclusions of early studies on this topic were not favorable; labor intensive construction methods were technically but not economically sound even at very low wage rates. Subsequent studies led to ways of improving the productivity of

traditional labor intensive tasks. The result of this second effort was remarkably fruitful: through a large number of small innovations, such as assuring that unskilled laborers have simple and effective hand tools, labor intensive civil works construction methods now are regarded as economically sound under a broad range of conditions.

These two examples underscore the importance of institutionalizing the technology generation process and the importance of a long term commitment to the generation of new technologies. For example, AID has provided support to the International Rice Research Institute's efforts to design simple farm mechinery, to fabricate prototypes, and to encourage small machinery firms to manufacture and sell that machinery commercially. This extremely complex activity is a long term effort involving far more than the generation of technically sound new farm machinery.

The principal justification for public support for the generation of new technology is the familiar "public goods" argument. 11/ Social returns to activities that generate innovations normally exceed private returns, often by a large amount. For example, Mansfield calculated the median social

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11/ See the Agency's Private Enterprise Development and Recurrent Costs Policy Papers.

and the median private rates of return for 37 U.S. innovations. The social rate (70%) was almost triple the private rate (25%). Such data strongly suggest that the case for public subsidies for applied research and development work is strong. 12/

Related data also strongly suggest that very few innovations fail for purely technical, engineering reasons. In a study of innovations that failed, Myers and Sweezy concluded that the principal problem was management error. 13/ Close attention to the financial and economic analysis of prospective innovations is crucial.

Research and development can be expensive. However, it is far more expensive to turn a technically feasible (potential) innovation into a commercial success than it is to turn a good idea into a technically feasibl innovation. Most of the costs and most of the risks involved in generating new technologies are incurred after technical feasibility has been demonstrated.

12/ Mansfield, Edwin, "How Economists See R and D," Harvard Business Review, Nov.-Dec. 1981, pp. 98-106. Manfield cites the case of an new type of thread that permitted higher sewing machine speeds. In turn, higher machine speeds led to cost reductions by garment manufacturers. For this innovation the social rate of return was about 300 per cent; the private rate of return was only 27 per cent.

13/ See Myers, Sumner and Eldon E. Sweezy, "Why Innovations Fail, Technology Review, 80, 5, March/April 1978.

These latter stages typically raise important issues such as purchasing, production, and marketing, issues best resolved by people trained in the social and management sciences rather than people trained in the natural sciences. The sooner these kinds of people are involved in, and have decisive control over, the innovation process the more efficient that process is likely to be.

One of AID's principal advantages over other donors is the scientific knowledge lodged in the U.S. academic and business communities. AID is committed to tapping the scientific capacity of the United States. By building closer relations with these U.S. communities, AID professional staff is better able to identify prospective and emergent technologies of great potential value to developing countries. By contributing financial support to specific scientific activities not otherwise expressly intended for applications in the developing countries, AID is able to leverage its resources and turn the attention of US scientists to helping solve development problems. AID, of course, will continue to strengthen its current programs with the academic and business communities such as the collaborative research support programs with U.S. Title XII universities. AID will continue to fund a small number of scientific research projects in carefully selected topics of particular importance to developing countries.

Diffusing Technology

There are two principal metaphors describing the diffusion of technology. The first reduces to a cliche: "build a better mousetrap and the world will beat a path to your door." The mousetrap metaphor emphasizes competitive market mechanisms for diffusing technology. The second metaphor looks to public diffusion mechanisms and takes as its model the agricultural extension system.

Markets and extension systems work reasonably well in developed countries; each has been carefully refined over time. Neither invariably works well in developing countries.

In the poorer countries, markets are thin. Transactions costs are high. Monopolistic and oligopolistic behavior, often permitted or even encouraged by government regulation, is common. Prices vary according to consumers' social status and other "non-market" variables. The range of alternative goods and services -- substitutes and complements -- is sharply limited. In general, markets work; however, fully competitive markets are not common and often function erratically.

Problems plague administrative technology diffusion mechanisms as well. Agricultural extension systems have proven reasonably sucessful at reaching the relatively large landholders who are part of the local rural elite. It is more difficult to adapt or restructure extension systems so that new technologies reach the poorer farmers. The agricultural

extension system provides the basic model for health, education and family planning outreach systems, which generally suffer from similar problems.

Competitive market systems typically allocate resources more efficiently than do administrative systems. AID will offer assistance that supports markets and that helps markets work more competitively, particularly markets involving improved technologies.

Many of the technologies AID helps transfer are in agriculture and in services such as health, family planning, and education. A small, if growing, share is in industries. The conventional wisdom is that technology diffusion in areas of particular importance to AID (agriculture and most basic services) are dominated by administrative mechanisms; in areas of lesser importance to AID (industries and some services, e.g., financial services) technology diffusion systems are dominated by market mechanisms.

There is some evidence that supports the conventional wisdom. AID policies, however, are based on two key observations. First, while administrative diffusion mechanisms often are critically important in reaching the production, consumption, and other goals of a comprehensive agricultural strategy, in no country has an effective administrative diffusion

mechanism stood alone. 14/ Years ago, in the U.S., numerous private mechanisms both complemented and provided competition to the public adminstrative system. Commercial agricultural processing firms, railroad companies, businesses selling agricultural inputs, and mail order supply houses all formed part of the larger comprehensive network of technology diffusion systems. Non-profit institutions such as county fairs, other formal and informal institutions such as 4-H clubs and the Grange, and word-of-mouth transmission of the results of the demonstration plot experiments of innovative farmers all were important in the U.S. AID projects that emphasize an administrative diffusion mechanism to the exclusion of complementary or competing alternatives will fail to take advantage of the symbiotic relationships involved. It is AID policy to explore actively private alternatives to administrative technology diffusion mechanisms and to encourage competition among different systems. In this way AID can best assist developing countries build more efficient technology diffusion systems.

14/ "A number of writers have pointed out that agricultural extension services which proved so effective in Europe and the United States have failed in the less developed countries because the supplementary goods and services provided by the market in western countries were not available in the LDCs." Ellis, Gene, "On Development from Below: Serve the People or Let the People Serve Themselves," Department of Economics, University of Denver, mimeo, no date, p. 20 (footnote suppressed).

Second, while markets are especially important in diffusing proprietary technologies typically associated with industrial activities, technology markets in industrial sectors of special interest to AID have some peculiar features. In particular, in manufacturing

> ... product areas as diverse as clothing, food processing, and furniture, the transmission of know-how and the operational tricks of production, are likely to be unimportant. Most of the products have been in existence for a long time; the combination of information available from capital goods producers, freely available trade knowledge, and occasional consultants can provide the basis for efficient production. 15/

Under these circumstances, there are two effective ways to stimulate the diffusion of technology. They are, first, to encourage private producers of relevant goods and services to establish effective marketing systems within developing countries, and second, to encourage the transfer of technologies that are peripheral to those involved in "the operational tricks of production." Both underscore the importance of understanding

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15/ Pack, Howard, "Technology and Employment Constraints on Optional Performance," in Rosenblatt, Samuel M. (ed.) Technology and Economic Development: A Realistic Perspective (Boulder, CO: Westview Press) 1979.

the various technology transfer mechanisms already in place before design project interventions, and of building institutions that support the adoption of market based solutions to problems of development.

International technology transfers are heavily influenced by the legal and policy framework. That framework defines, for example, the nature of management and other licensing agreements, and transactions involving patents, trademarks, copyrights, and trade secrets. In addition, developing countries often inhibit the use of imported technologies in food, medicine, national defense, and other areas regarded to be in the public interest. The incentives for U.S. firms to engage in technology diffusion activities is accordingly reduced in these areas. AID can provide meaningful assistance to developing countries by analyzing the legal and policy framework within which international technology diffusion occurs. Similar investigations of the legal framework affecting wholly indigenous diffusion also merit support.

The technological absorptive capacity of most developing countries is very limited. The phrase "absorptive capacity" usually is taken to refer to scientific and engineering institutions such as universities, research laboratories, engineering facilities, technical training institutes, industrial standards organizations, and the like. AID will continue to help strengthen these kinds of institutions.

However, the absorptive capacity in most developing countries is limited primarily by the tentative connection between the scientific and technological institutions of a country and the ability of that country's private sector to turn technical knowledge to socially productive use. It is this area in which AID can make its greatest contribution.

AID explicitly recognizes that the technological absorptive capacity of a country is not usefully defined solely in terms of its ability to conduct scientific research and applied engineering activities. A new technology will not be broadly adopted unless suitable -- and ostensibly non-technological -- institutions are in place and working effectively. These institutions are formal and informal, modern and traditional. They include institutions that provide short term and long term credit, managerial and technical training, raw material and intermediate inputs, marketing services, maintenance and repair services, information, and a host of other goods and services. Accordingly, AID will support not only scientific research and engineering institutions but also those ostensibly non-technological institutions, formal and informal, modern and traditional, that provide the supporting goods and services that

directly facilitate technology diffusion through markets. 16/

Acquiring Technology

Acquisition is the forgotten act in technology transfer process. The prospective acquirer of a new technology too often is ignored because he, or she, is not the key decision maker.

Even where the prospective acquirer clearly is the key decision maker, development planners and foreign assistance agencies pay far too little attention to that individual. In his massive study of a number of International Executive Service Corps (IESC) projects, Wallender found that the key obstacle to absorbing technology in developing countries is the lack of managerial skills necessary for problem diagnosis and planning. 17/ The kind of industrial and service firm -- small

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16/ As many observers have noted, what is usually most urgently needed in developing countries is not an increased capacity to generate new or adapt existing technologies but an increased capacity to turn both existing and new technological knowledge to commercial or other socially productive advantage. There are countless research institutes in developing countries too poorly equipped to push forward the frontiers of science and too "ivory tower" to produce technologies of commercial value. As observed by Ranis, many of these institutes are "expensive white elephants which contribute neither to science nor to technology." See Beranek, W. and G. Ranis, Science and Technology and Economic Development (New York, Praeger) 1978. See also Crane D., "Technological Innovation in Developing Countries: A Review of the Literature", Research Policy, 6, 1977.

17/ Wallender, Harvey W., III, Technology Transfer and Management in the Developing Countries, Executive Summary (New York: Fund for Multinational Management Education) 1979, p. 1.

scale, labor intensive, using relatively unsophisticated technology -- of particular interest to AID typically has not yet developed the capacity to identify and assess its technology needs. Accordingly, management assistance designed to build this capacity at the level of the firm frequently is the first order of business. Improved management will enable individual business firms to take advantage of existing information on technology and to identify, adopt, and adapt already available technologies to meet the specific needs of those firms.

AID will adopt a three part analytical structure to explore the role of prospective acquirers. The first step is to adopt a presumption of rationality. People in developing countries who acquire new technologies, including farmers, street vendors, small scale industrialists, unskilled laborers, and others, are rational: they respond to economic incentives. Schultz's "poor but efficient" hypothesis is the basis for any meaningful study of the acquisition of technology. 18/ AID officials, observing the reluctance of a peasant farmer or an industrial entrepreneur to adopt a given new technology, no longer immediately conclude that that individual is ignorant, wedded to outmoded traditions, or otherwise dull.

18/ See the "poor but efficient" thesis developed by Shultz to apply to peasant agriculture. Schultz, Theodore W., Transforming Traditional Agriculture (New Haven: Yale University Press) 1964.

But rational behavior is not always easily recognized. For example, a traditional blacksmith "knows" for which a purpose a given piece of scrap steel is best suited by "feeling" it and by "smelling" the sparks it gives off; the blacksmith knows nothing about carbon content. Similarly, a farmer "knows" which crops grow well by feeling the soil without being able to convert that knowledge into a pH value. A mechanic "knows" that a bearing soon will fail by listening to what the motor "says" as it runs. The technical knowledge embodied in these skilled workers is not lightly tossed aside. The second step in taking into account the acquirer in the technology transfer profess is to study, thoroughly and sympathetically, existing patterns of the behavior of prospective adopters.

The third, final, step is an assessment of the risk perceptions of prospective acquirers. People who acquire new technologies exhibit entrepreneurial behavior; entrepreneurs typically assess risky alternatives and, through the market-place, reap the rewards of success or suffer the punishment of failure. Efforts to identify and to promote entrepreneurial behavior will stimulate the acquisition of useful technologies.

In broad terms, the best way of encouraging the acquisition of new technologies is to improve the returns to adoption or to reduce the perceived risks of adoption. Industrial development planners must learn lessons well known to agriculturalists: adopting new technologies may result in wider fluctuations in

output from year to year (greater risk) as well as higher average annual production levels (greater returns). Sudden shortages in available transport or power, sudden shifts in consumer demand or other factors positively associated with more complex, modern technologies may disrupt production or sales. In addition, the fluctuations associated with the new technologies will not be known while those associated with established technologies are well known. Both risk and uncertainty accompany any decision to adopt a new technology. 19/

Summary

Several policies emerge from this discussion of the broad framework for analyzing technology transfer. It is AID policy:

- in the realm of technology generation:
  - o to institutionalize the process of generating continuing streams of new technology;
  - o to make long-term commitments in promising technology areas;
  - o to justify support for project activities in terms of uncaptured positive externalities; (the "public goods" argument).

19/ For an excellent paper on risk, technology, and institutions, see Runge, C. Ford, "Weighing the Risks of Change: Technology, Institutions and Project Implementation", AID, Bureau for Science and Technology, 1983, mimeo.

- to devote relatively more resources to solving management, marketing and related problems of generating new technologies;
- to continue to fund a small number of basic scientific research projects in carefully selected, specific topics of particular importance to developing countries.

in the realm of technology diffusion:

- to help make more efficient and more competitive the markets that diffuse technologies in developing countries;
- to explore private alternatives to administrative technology diffusion mechanisms;
- to analyze the legal and policy framework affecting the diffusion of technologies originating outside as well as inside the developing countries;
- to improve the technological absorptive capacity of developing countries by increasing the ability of those countries to turn technical knowledge to commercial advantage.

in the realm of technology acquisition:

- o to increase recognition by AID staff of the importance of the acquirer of new technologies;
- o to stimulate the demand for new technologies by supporting efforts by prospective acquirers to upgrade their managerial skills;
- o to adopt a three part analytical structure to explore the role of prospective acquirers of technology by:
  - -- assuming rational behavior;
  - -- studying existing patterns of technology acquisition;
  - -- assessing the perceived risk and uncertainty of new technologies.

AID POLICY ON TECHNOLOGY TRANSFER

If you give a fish to a hungry man, you help him but he will be hungry again tomorrow. If you teach him how to fish, you help him avoid hunger. You have transferred a technique. But conditions change. Fishing resources may dwindle; the fishing technique you have taught may not always "work." It is not enough to transfer a technique.

If you teach a man a problem solving process -- how to catch fish -- and if you institutionalize that process, then you have taught him how to adapt fishing techniques to an ever changing environment. You have transferred a technology.

Rather than merely helping him attain a new, higher plateau of stagnation, you have helped provide him an innovative capacity, a capacity to increase production through time. AID's objective in the technology transfer area is not merely to help developing countries increase production; it is to help create and strengthen innovation systems that will lead to continually increasing production levels, in a sustainable fashion, over a long period.

AID's policies in this area are intimately linked to the three other key policy areas of the Agency: institution building, policy dialogue, and private enterprise development. These three policy areas will be discussed in turn.

Institution Building

In the 1960s, the effort to build a scientific, and to a lesser extent technological, capacity was ill conceived primarily because that capacity was, and in most developing countries still is, quite isolated from commercial activities. AID policies on technology transfer are based mainly on the effort to "demarginalize" -- to make useful -- existing and newly generated technologies. This is primarily an institution building process.

In agriculture, AID will emphasize efforts to increase the capacity for technological absorption at the level of the farm. In industry and services, AID will emphasize efforts to increase the technological absorptive capacity of the firm. Technological absorptive capacity can be increased by relying on demon-

strations and field trials, increasing the flow of information to potential acquirers, providing managerial and other assistance to define technological needs, emphasizing the need to adapt technologies to heterogeneous local conditions, offering training in select areas, and reducing business risk by improving information systems. Central to these efforts is a recognition of the crucial role played by the ostensibly non-technological institutions that facilitate the technology transfer process. Through these institutions, farmers and firm owners gain access to credit, raw materials and productive inputs such as fertilizer or pig iron, marketing know-how, and trained workers.

In broad terms, AID increasingly will turn to efforts that stimulate the demand for new technology. In the past, donor agencies in general, including AID, emphasized the generation of new technologies. It remains AID policy to assist research and other institutions that are developing new seed varieties, new vaccines, and other promising scientific advances. It remains AID policy to assist engineering and other institutions that are developing new water lifting devices, adapting road construction methods to labor surplus contexts, and devising other promising technologies. However, AID believes that too little attention has been paid to alleviating the constraints

on the demand for technologies in developing countries. 20/ Accordingly AID will move from a top-down, physical-science-based approach dominated by the judgments of "experts" toward a bottom-up, social-science-based approached dominated by the judgments of "the market."

Policy Dialogue

Most problems in technology transfer, when thoroughly identified, frequently have less to do with technical matters than with matters of policy. Price distortions often are crucial. Otherwise sound efforts to increase the productivity of small farm agriculture may fail if farm-gate prices offer inadequate production incentives. The price of credit frequently is subsidized for powerful producers and is prohibitively

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20/ Wallender's work is emphatic on this point (see footnote 17, above). In general, the academic literature increasingly recognizes that the binding constraints to adopting technological solutions to development problems typically are found on the demand side. AID's project impact evaluations provide supporting evidence.

The agricultural extension model is an example of a supply oriented approach to technology transfer. It is essentially a top-down, technology-push (in contrast to a demand-pull) model. In brief, outside "experts" identify problems in technical areas (irrigation, grain storage, seed stock and the like); research scientists assess the relevant fields and generate technical solutions to these problems. These laboratory solutions are tested and refined. Suitably adapted they then are diffused through extension agents who demonstrate those technologies and urge farmers to adopt the technical packages.

expensive for the politically weak; otherwise sound efforts to help potentially productive but politically weak producers may fail as a result. These and similar problems often appear to be technical; they are in fact best addressed as part of a policy dialogue with the host country government.

AID project designers should explore thoroughly the policy context of all projects with high technology transfer components. Policies affect the full spectrum of the technology transfer process, embracing the generation, the diffusion, and the acquisition of technology. Both domestic and international policies should be examined. Import substitution policies can be as damaging to efforts to promote a good technological package as can internal credit policies. The international transfer of technology is especially important to AID.

AID supports efforts to strengthen the competitive nature of markets in technology, whether domestic or international. Quite often, few prospective buyers and sellers of a given technology are in the market at any particular time. Where technology markets are thin, AID investments in information may be very productive. The international transfer of technology is especially important to AID. It is AID policy to encourage new forms of technological collaboration with small and medium sized U.S. firms; to assure the enforceability of contracts; to establish suitable procedures to resolve disputes involving

bundled or unbundled technology transfers, and to engage in negotiations over legal provisions that inhibit the transfer of technology.

In general, it should be noted that untrammeled free markets seldom -- if ever -- exist. Rules, codified or not, govern market transactions. AID project designers must understand these rules just as they must understand the forces of market behavior. That markets in technology transfer often are thin underscores the importance of the policies, procedures, and practices that govern market transactions.

Private Enterprise Development

It is AID policy to rely on the most efficient technology transfer mechanisms possible. These mechanisms typically are private, market systems. If market mechanisms are available but are weak, they should be strengthened. If they do not exist, they should be created. Support for administrative mechanisms must be explicitly justified in economic terms. If administrative mechanisms are supported, AID projects must recognize the crucial complementary role of private commercial systems. To strengthen administrative mechanisms at the expense of market mechanisms is not a permissable use of AID funds.

Project designers should identify potential obstacles to the generation, diffusion, and acquisition of technology. The costs of acquiring information on technology, of screening or assessing

technology, of adapting technology, and of training people to use that technology can be very great. One of the most glaring deficiencies in small firms is the inability of the entrepreneurs to define and to assess their own technology needs. AID can stimulate demand for appropriate technologies by providing suitable management assistance to these entrepreneurs. Similarly, helping small scale farm operators better define and assess their technological needs, in a dynamic context, will stimulate demand for appropriate agricultural technologies.

In general, AID will not support activities in which continuing subsidies are required. AID recognizes that returns to research and development expenditures seldom are easily captured by competitively organized private business firms. And it may be noted that some of the institutions that define a nation's technological competence may be characterized by increasing returns to scale. In a few instances, subsidies may be warranted if social returns clearly exceed private returns. However, alternatives to government subsidies frequently can be found. Business leaders may agree, in their own interests, to form associations; such associations may assess their own members fees to support research or other activities not otherwise readily justified. AID encourages the use of creative private solutions to problems involving positive externalities.

AID will support projects in which markets for technologies are made more efficient. The best way of meeting this objective

is to introduce additional competition into those markets. AID also will support projects that emphasize the adoption of proven technologies through commercial means. AID encourages alternatives to full blown publicly supported extension systems. These alternatives typically will involve cooperation with public systems and competition among private firms.

Broad Agency Directives

AID will continue to support projects that help meet the basic human needs of the poor. In each country, the technology transfer process must be based on an assessment of individual country development needs that focuses on beneficiaries. The mission's country development strategy statement is a crucial statement and will frame the mission's technology transfer programs. Taking into consideration host country priorities and other donor activities, the mission will identify specific technological priority areas and constraints. Policy papers on specific sectors (e.g., health, domestic water and sanitation. and agriculture) and on specific topics (e.g., recurrent costs, pricing, and subsidies in agriculture) will guide the missions. Missions will keep in mind the importance of replicating successful instances of technology transfer.

As the development agency of the U.S. Government, AID is concerned primarily with transfers taking advantage of expertise in which the U.S. has special capabilities. Such fields of expertise certainly would include agriculture and agribusiness;

the U.S. developed key components of the widely respected research-extension-training system that generates and diffuses agricultural technologies in many developing countries. The U.S. also has special expertise in the small scale enterprise (industry and services) field so heavily populated by dynamic entrepreneurs. Finally, the U.S. is a world leader in industrial applications of high technology; these sophisticated applied technologies occasionally are of great value in promoting development.

AID's technology transfer policies explicitly recognize differences in the technological capacities of the developing countries. AID's broad "two-tier" approach is based on an assessment of the technological capacities of those countries in key sectors (e.g., agricultural production, small scale industries, and social services) of particular interest to AID. In general, the closer a developing country comes to "AID graduate" status, the more likely that country is to have a relatively well developed technological capacity.

Economic Analysis

Some experts in technology transfer argue that, at the project level, knowledge of the site specific characteristics -- not the technology specific characteristics -- is the key to successful project design and implementation. 21/ This follows

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21/ See McInerney John P., "The Technology of Rural Development," World Bank Staff Working Paper No. 295, 1978.

from the observation that most technology intensive projects that fail do so because the technologies involved do not "fit" correctly the physical, social, cultural, political or economic environment. While all these dimensions of fit are important, the economic dimension is most crucial: the principles involved in choosing an appropriate technology are best defined using the analytical methods of economics.

In general terms, an economic analysis includes references to "check list" items such as criteria for appropriateness: capital cost per workplace, employment intensity, local capacity for maintenance and repair, and active participation of the beneficiaries. Such an analysis also includes descriptions of specific relevant markets: patterns of unequal access, the legal and practical basis of exchange (e.g., the enforceability of contracts), and the potential for exploitation through markets. A base survey of the proposed project's target beneficiaries and their access to and influence over resources through a broad range of social and cultural institutions usually is useful.

In addition, a more analytical economic analysis also is called for. A cost/benefit analysis should be performed if feasible. Shadow prices must be used -- at the project formation stage -- if cost/benefit analysis is to have any impact on technological choice. There is no other meaningful way to estimate the effect of distorted price signals.

Structurally induced price distortions are common. For example, the absence of formal rural financial markets may mean that farmers and rural business owners must pay higher interest rates than otherwise would be necessary. Capital may not move easily to rural areas because of this structural problem. As with policy induced price distortions, the best approach may be direct: AID should help build the rural financial institutions that will help eliminate credit price distortions.

A cost/benefit analysis will help identify these distortions. To the extent possible, cost and benefit streams should be quantified and discounted to a present value. The project should be evaluated, in the best manner possible, according to a review of the "with project" and "without project" scenarios. Risk/returns matrices should be used where needed. Sensitivity analysis should be conducted.

But the cost/benefit analysis should not be undertaken as a mechanical requirement of the AID project approval process. While AID is continuing to strengthen its ability to conduct sound economic analysis, performing such analyses involves primarily a way of thinking about project design. A sound economic analysis does not result in placing on a pedestal the internal rate of return or the benefit/cost ratio (or, in the complementary financial analysis, the profit rate); it does result in a way of thinking that emphasizes, for example, oppor-

tunity costs, discount rates, alternative approaches, specific benefits accruing to specific target populations, market processes, overall economic efficiency, real (rather than nominal) returns, and the nature and the identity of the decision maker or decision makers. Above all, it emphasizes the important injunction: "get prices right."

POLICY IMPLICATIONS

AID's field missions continue to have the primary responsibility of assessing local conditions and designing the principal interventions. Each mission will need to build a strong analytical base, beginning with a sound country development strategy statement. Specific projects will be subject to rigorous economic analysis especially in the early stages of project design.

Project proposals will be reviewed and approved with a clear understanding that flexible implementation procedures are especially important in projects in which the technological component is significant. There are two reasons. First, the effects of introducing new technologies are notoriously difficult to predict well. Second, markets which play so forceful a role in AID technology transfer policies, are constantly changing. Combining technologies, with their unanticipated side effects, and markets, with their penchant for continual change, calls for a great deal of flexibility in project implementation.

The Bureau for Science and Technology (S&T) is primarily responsible for the research activities of the Agency. 21/ These activities are crucially important for keeping the missions fully informed of the latest thinking on potential applications of scientific and technological changes taking place in the U.S. and abroad. AID sponsored research generates new knowledge of great potential use to developing countries. In order to diffuse this knowledge rapidly, through private means, AID is exploring a variety of legal mechanisms involving patents, royalty free licenses, and "march-in rights".

The S&T Bureau also will continue to provide support services to the missions. The bureau will be particularly sensitive to issues of technology policy, commercial applications of technology and the institutional context that provides the setting for technological change.

21/ See the policy determination on research, forthcoming. AID's policy on research recognizes that the generation of new technologies is an important, if small, part of the technology transfer process. Support for research and development (R&D) should not dwarf support for the diffusion and acquisition components of the technology transfer process. See, for example, the Center for Policy Alternatives, Policy Choices (Massachusetts Institute of Technology, Fall 1982).

Mission views on the most appropriate role for research on new technologies emphasize applied research especially on the adaptation of, and the factors influencing the adoption of, proven and commercially viable technologies. A fascination with technological hardware at the expense of software, and with leading technologies at the expense of commercially viable alternatives is counterproductive.

AID already is committed to increasing the share of its financial resources devoted to technology transfers, as opposed to simple resource transfers. AID will emphasize:

- those technology transfer projects that build or strengthen innovation systems leading to sustained increases in production, over time, in a changing environment;
- those technology transfer projects that clearly rely on market principles in the generation, diffusion, and acquisition of technology;
- those technology transfer projects that clearly recognize, and, as appropriate, seek to change the practices and the policy framework within which technology is transferred.

AID will seek to better balance its technology transfer programs by increasing:

- its understanding of existing diffusion mechanisms and of the acquisition component of the technology transfer process;
- those activities that stimulate demand for technologies that are, or are reasonably judged soon to be, commercially viable;
- those activities that are devoted to social science based technologies such as those involving business management, market diffusion mechanisms, and local user associations.