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Appropriate Technology as a Development Strategy for Rural Areas in Developing Countries

by

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Introduction

This paper is concerned with the rural and peri-urban poor as the intended beneficiaries of the application of technology. The first part tries to clear up some of the confusion surrounding the definition of "appropriate technology". The second part briefly describes a few of the ongoing projects supported by Appropriate Technology International (ATI) to implement this strategy of development. The third part examines the lessons learned from some case studies that ATI has commissioned of appropriate technology projects sponsored by various organizations. The fourth part briefly summarizes the main findings of a set of studies ATI has commissioned on the effects of government macroeconomic policies on the adoption of appropriate technologies.

The Definition of Appropriate Technology

There are two alternative views on the definition of an appropriate technology: the social welfare approach and the technology specifications approach. In the social welfare view, a mix of technologies should be chosen that maximizes achievement of the objectives of a society. Although this concept has appeal, it is difficult to operationalize because social objectives are not clearly specified and are often in conflict, and it can be difficult to quantify the expected effects of a technology a priori. There is no nonsubjective method of determining the value weights placed on various objectives and the shadow prices needed to correct for the market distortions in an economy (Stewart 1986a).

Under the technology specifications approach, the expected outcomes of a technology are compared to a list of characteristics that are generally associated with the concept of "appropriateness". In this context, appropriateness is usually defined in terms of the socio-economic impacts on the poor in rural and/or urban areas, and on the environmental impacts. Technology specifications lists are also subjective and often confuse short-term and long-term impacts. A technology may satisfy a particular criterion to varying degrees and few technologies are likely to meet all of the specifications of appropriateness. However, the technology specifications view does offer "sign-posts for action" (Ibid.).

Consequently, it may be best to combine these two approaches. A list of criteria for appropriateness may be developed and refined from the experience gained in assessing the impacts of technologies in use. The criteria can then be used to screen technologies, narrowing down the candidates for in-

depth appraisal using benefit-cost analysis and other techniques for social and environmental impact analysis (Hyman, Stiftel, Moreau, and Nichols 1986).

The following discussion lists some of the commonly held charateristics of appropriate technologies. The appropriateness of a technology depends on how it is used, what it is used to produce, and who gains and loses as a result of the production and consumption decisions. Appropriate technology projects typically differ from conventional technology projects in their reliance on small-scale equipment and processes (often locally made), and different amounts, kinds, and sources of raw materials. Compared to conventional technologies, appropriate technologies typically are less capital intensive; more labor intensive; less dependent on scarce foreign exchange for imported goods; and easier to operate, maintain, and repair. Yet, appropriate technologies are labor saving in comparison to traditional methods of production.

It is often claimed that appropriate technologies are more productive per unit cost than either conventional or traditional alternatives. As a result, the final outputs are often less expensive for consumers than those of conventional technologies and of superior quality to those of traditional methods. Other hypothesized benefits of appropriate technologies are a high potential for significant impacts on the economic and social well-being of the poor and a greater likelihood of sustaining natural resource stocksand environmental quality.

Appropriate technology projects are often based on the premise that development strategies will be most cost-effective and will have the fewest unintended, negative impacts when low-income people can own and operate profitable enterprises that match their skills and resources. These projects may be designed to increase their access to goods and services, raw materials, financing, technical information, and/or markets. This strategy also increases the participation of the poor in the development decisions that affect them. These opportunities have frequently been neglected by commercial sources of capital because they are relatively risky, small-scale, and non-urban. In many cases, it is necessary to collaborate with grassroots organizations that are capable of identifying local opportunities and coordinating the services needed to achieve success.

In order to test assumptions about the degree of success in the dissemination of technologies, it is useful to classify the state of the technologies: traditional, upgraded traditional, off-the-shelf modern, downscaled modern, and innovative replacement.

***Traditional technologies** are those that have been used in production or consumption for a relatively long time (generally at least 25 years). In some cases, they might have been introduced from another less developed country rather than being of indigenous origin. Traditional technologies usually rely on human or animal power, or renewable energy resources.

***Upgraded traditional technologies** incorporate key elements of traditional technologies, but have been improved to take advantage of the potential for higher inherent efficiencies(e.g. thermodynamic properties or extraction rates) or economies of of scale.

***Off-the-shelf modern technologies** have been in use for a relatively short time, generally less than twenty-five years. They are often larger in scale than traditional technologies.

***Down-scaled modern technologies** are versions of modern technologies that have been adapted for a smaller scale of production or consumption, or to match the available resources.

***Innovative replacement technologies** are generated by application of new scientific and engineering knowledge.

Each of these types of technologies may be appropriate for particular situations in less developed countries, but the approach of upgrading traditional technologies is often the most cost-effective way of reaching the rural and peri-urban poor. James (1984) notes that upgraded traditional technologies often retain the accumulated environmental knowledge of local people and are more compatible with cultural values, local skills, and resources than are down-scaled modern technologies. This environmental knowledge incorporates physical factors such as climate, hydrology, and soils; ecological factors; the degree of development of economic infrastructure; and relative factor prices. Cultural values include work roles and attitudes toward risk. The availability of skills for maintenance and repair can be nearly as important as the availability of skills for use of the technology.

James (1984) also notes that in down-scaling modern technologies, many of the economies of scale that make the technology efficient may be lost. Moreover, the products of down-scaled modern technologies may be less suited to the incomes and preferences of low-income or rural consumers.

Most off-the-shelf modern technologies and innovative replacement technologies tend to be less appropriate for small farms and firms in less developed countries because the research that produced these technologies was carried out in developed countries where the relative factor proportions are very different. However, some of the older modern technologies may be appropriate, especially for medium-scale, urban enterprises (Pack 1981).

ATI's Field Program

Appropriate Technology International (ATI) is a not-for-profit development assistance corporation chartered by the U.S. Congress and funded by the U.S. Agency for International Development (AID). ATI operates in Africa, Asia, Latin America/Caribbean regions. ATI works with nongovernmental organizations and private enterprises in developing countries to identify, adapt, and disseminate technologies appropriate to the needs and resources of the rural and peri-urban poor. ATI field tests the application of innovative technologies and dissemination strategies to demonstrate their replication potential.

The field program is carried out by Washington-based project officers who have considerable experience in their regions. The project officers spend about one-third of their time in travel, visiting each project 3-4 times per year and identifying new project opportunities. Technical support is provided by specialists in the Evaluation and Technical Development (ETDG). Prospective projects are reviewed internally by ATI's management and also by an external Project Review Advisory Committee and ATI's Board of Directors.

Other members of the ETDG staff apply ATI's monitoring and evaluation system which is structured around an information framework (Hyman and Corl 1985). This framework is a checklist that facilitates consistency in the collection and analysis of data on the productive activities in ATI's projects. Much of this information comes from quarterly progress and financial reports by implementing organizations and trip reports by ATI's project officers and ETDG staff. Where necessary, ATI obtains additional supplementary information through special studies or surveys carried out by implementing organizations or local universities or research institutes.

ATI's field program currently concentrates on three priority technical fields: (1) the processing of agricultural products and use of agricultural residuals, (2) the processing of mineral resources for local use, and (3) the production and distribution of equipment and other support for small farms. ATI also occasionally supports projects

outside of these three technical fields. Table 1 lists ATI's current portfolio of projects. An example of a project in each of these areas is briefly described below.

Sunflowerseed Oil Extraction. Without a mechanical device, it is difficult to extract oil from the hard seed of the sunflower. ATI has provided technical assistance and financing to a medium-scale, private sector workshop in Tanzania (the Themi Farm Implements and Engineering Co.) for the production of two types of manually operated oil presses for sunflower seeds (they can also be used to extract oil from palm nuts, copra, and peanuts). Each of these machines fills a different market segment.

The first press is a larger machine designed at the Institute for Production Innovation at the University of Dar es Salaam. When this press is used with a centrifugual impact dehuller and a seed crusher, about 60 liters of oil can be produced per day from 200 kg of sunflower seeds. This equipment is much less expensive to purchase and operate than a diesel-powered expeller. Medium-scale farmers and small-scale enterprises that sell oil extraction services are buying this equipment directly from the manufacturer.

The second press was designed by an ATI engineer. It is much smaller, less expensive, and less subject to wear because the extraction pressure is applied by a reciprocating ram rather than a rotating screw. This press can produce 68 liters of oil per day from 200 kg of sunflower seed, but at a slower rate of about 24 liters per day. A follow-on ATI project with Lutheran World Relief is providing financing through a revolving loan fund so that village groups can buy this press.

Lime Kiln Technology. This is a two-stage project being implemented by the Instituto Technologico de Costa Rica. The first stage was for applied research and development to modify the traditional lime kiln design. Under the second stage, support will be provided to encourage small-scale lime producers to modify their existing kilns. Improvements will also be made in other aspects of lime production -- crushing of limestone; and milling, hydration, and packaging of lime.

The improved kiln runs on a continuous process rather than a batch process. This reduces fuelwood use because the kiln does not have to cool down for unloading and then heat up again to reach the necessary temperature for burning lime. Other changes distribute the heat more evenly, recirculate hot gases, and reduce heat losses through the top and sides of the kiln. These changes decrease fuel costs by one-third while reducing labor costs, improving occupational health and safety, and allowing a tripling of the monthly output. The modifications cost about $2,000 per kiln. The improvements in the kiln and the associated processes will increase the quality of the product so that it can replace the lime

Table 1

ATI's Current Portfolio of Projects

Brief Project Title	Country	Funding ($)
Africa		
Palm oil extraction	Cameroon	304,324
Animal-driven pumps	Botswana	108,000
Agro-industries	Zimbabwe	224,500
Biogas refrigeration	Mali	13,445
Brick production	Botswana	90,400
Oil press production	Tanzania	112,276
Rural potteries	Tanzania	97,512
Village oil extraction	Tanzania	142,676
Improved bricks	Tanzania	156,452
Lime production	Botswana	95,000
Grapple processing	Botswana	37,100
Shea nut butter	Mali	52,070
Improved charcoal stoves	Kenya	254,097
Anguh maize mills	Cameroon	164,084
Hydro-powered grainmil	Zaire	282,580
Grain dehullers	Mali	132,318
Asia		
Venture capital company	Indonesia	300,824
Rhizobium inoculant	Thailand	137,700
Rural small-scale industries	Thailand	310,733
Protein-enriched cassava feeds	Thailand	210,300
Rural small industries development	Philippines	367,440
Wool spinning	Nepal	165,144
Turbine-driven agro-processing	Nepal	29,959
Computer video training	Sri Lanka	240,076
Organic fertilizer production	Philippines	107,957
Industrial salt and chemical byproducts	Philippines	151,791
Latin America/Caribbean		
Improved lime kilns and lime processing	Costa Rica	144,514
Cassava processing	Haiti	86,821
Swine feed technology	Dom. Republic	160,977
Linares pump	LA/C Region	18,200
Improved wheelchairs	LA/C Region	300,800
Annatto production	Peru	161,691
Farm support enterprises	Mexico	221,000
Small-scale placer mining equipment	Peru	177,376
Potato-based foods	Peru	312,982

imported for sugar milling and leather tanning, and substitute for cement in housing and road sub-base construction.

Rhizobium Production. Rhizobia are nitrogen-fixing bacteria that have a symbiotic relationship with the root nodules of legumes such as soybeans, peanuts, and mung beans. Rhizobia exist naturally in some soils where legumes have been grown, but their effectiveness can be augmented by inoculating the seeds before planting. By converting atmospheric nitrogen into a form that plants can use, rhizobia reduce the need for nitrogen fertilizer. The use of rhizobium inoculant can increase the productivity of legumes by 20-50%. Chemical sources of nitrogen are often imported into developing countries and they are expensive and constitute a large share of the cash costs of small-scale farmers.

Rhizobium inoculant has a short shelf-life, particularly under tropical weather conditions. Few small-scale farmers in developing countries are aware of the benefits of the inoculant and most would not have easy access to rhizobium produced in a large-scale plant because of distribution problems.

As a result, ATI is supporting SVITA (an applied R & D organization in Thailand) to scale down the technology so that inoculant can be produced by small, decentralized firms in a commercially viable manner. Following the recommendation of NifTAL (a research center on nitrogen fixation located in Hawaii), SVITA is experimenting with a dilution technique for rhizobium production. Since the demand for rhizobium inoculant is seasonal, SVITA is exploring the possibility of other products that can be produced using some of the same equipment. While the commercial-scale production process is being perfected, SVITA is working with a soybean growers association to test the product of the lab-scale technology. The association will also be involved in the dissemination of the technology to farmers.

Improved Wheelchairs Project. ATI has supported the development, field testing, and manufacturing of the Hotchkiss wheelchair design. This wheelchair is light-weight, adaptable to individual fittings, and durable. It has good traction and stability for travel over rough ground and can be folded for easy transport and storage. This wheelchair can be manufactured locally at $150-200, which is less than the cost of imported wheelchairs. Production is labor intensive, requiring 25-40 hours of work per chair in a flexible, batch process. ATI has provided financial and technical assistance to 12 small-scale workshops in Latin America for the production of this wheelchair in Brazil, Colombia, Guatemala, Honduras, and Peru. Each of these enterprises has a current capacity of 100-300 wheelchairs per year. In addition, ATI is promoting the replication of this

technology by providing a manual describing the construction of the wheelchair (Hotchkiss and Ramsden 1985) and a tool kit and set of jigs at cost ($20 for the manual and $1,000 for the tool kit and jigs).

Case Studies of Appropriate Technology Projects

Since the concept of appropriate technology is based on the premise that a technology must be matched to the needs and resources of a particular application, a case studies approach is important in documenting the economic, social, and environmental effects of technology choice. The ability to generalize from a case study depends on the degree of similarity to the study area. Many appropriate technologies have a high replication potential in large areas of the Third World.

The choice of technology has direct economic effects on wages, employment, and the distribution of profits from production. It also has direct effects on the range of choice of consumer goods and the real income of consumers. These effects from production and consumption vary across different groups such as the unemployed, part-time workers, full-time workers, and owners of productive assets (e.g. capital, land, and natural resources). The economic effects may also be tabulated by income group, ethnic group, gender, and location (rural, peri-urban, or urban).

The choice of technology has other social effects. Some of these effects are indirect because although they are associated with the increases in income, they depend on how the income gains or increased government revenues are spent. There may be indirect social effects on nutrition and health, public safety, education, population growth rates, and migration rates. Some possible social effects are more difficult to measure or attribute to technology choice (e.g. quality of life, participation in decision making, political stability, and moral upliftment). Consideration should also be given to environmental impacts and use rates for renewable and nonrenewable natural resources.

Short Case Studies of High-Impact Technologies

ATI has prepared a set of short case studies on eight appropriate technology projects supported by various donors that have had a widespread impact (Fricke 1984). These case studies include (1) handpumps in India, (2) oral rehydration therapy worldwide, (3) water pumping windmills in Argentina, (4) bamboo-reinforced concrete rainwater storage tanks in Thailand, (5) bamboo tubewells in India, (6) labor-intensive rural access roads in Kenya, (7) pappad processing in India, and (8) small farm implements in Tanzania. These are briefly

discussed below, with the exception of the fourth one which is covered in greater detail under the next subsection. The discussion of the eighth case above has been updated by Hyman (1985b).

Handpumps. More than 600,000 Mark II handpumps had been installed in Indian communities by the end of 1984. An average of 200-250 people are served at each installation. This reciprocating piston vertical displacement design was developed by UNICEF and the Indian government. It is manufactured by small workshops in India using domestically produced materials and meeting the specifications of Indian government standards.

The success of this handpump can be attributed to its low cost, durability, ease of maintenance by relatively unskilled labor, and the availability of spare parts. A three-tiered maintenance system with responsibilities at the village, subdistrict, and district levels has been established in some areas to avoid the usual problem of having idle, unrepaired pumps in rural areas.

Oral Rehydration Therapy. UNICEF, AID and other international agencies have promoted oral rehydration therapy (ORT) to reverse the dehydration caused by acute diarrhea, which claims the lives of over 5,000,000 children per year. The use of ORT during a cholera epidemic in Bangladesh lowered the death rate from 25% to 3.6%. Over the past 15 years, ORT programs have spread throughout the Third World. Approximately 80,000,000 individual packets of this mixture of glucose and electrolytes are distributed each year. Before the development of ORT, expensive intravenous methods of rehydration that required sterile facilities had to be used. Today, ORT packets are being manufactured in over 20 less developed countries. In the absence of the manufactured product, a homemade mixture of sugar, salt, and water can be used instead.

The ORT technology has been successful because it is simple and inexpensive. In some countries, major promotional campaigns have been conducted through the media and at the grassroots level to convince local people to use ORT.

Water Pumping Windmills. Approximately 60,000 water pumping windmills are in use in Argentina, mostly to provide water for livestock. This is a high-valued use of water because relatively small amounts are needed to sustain a typical herd and Argentine beef is of high quality. About 1,500-2,000 windmills are now being produced in Argentina each year by over 20 manufacturers. The standard windmill is a horizontal-axis lift design modeled after the U.S. multiblade fan type. Although this windmill does not have as efficient a mass-to-output ratio as some of the newer U.S. models, this proven design requires less precision in manufacture and is less expensive and easier to maintain than the most

technically advanced alternatives. These windmills can last 20 years.

The windmill technology was successfully transferred through licensing and franchising agreements that included financial and technical assistance and quality control standards. Other manufacturers have entered the market and Argentina now even exports windmills to the United States. Widespread adoption of the technology took place because the wind regimes, water table, and pasture land in large areas of the country are very suitable for wind pumping of water.

Bamboo Tubewells. The bamboo tubewell is a low-cost alternative to conventional wells with green bamboo replacing the cast iron pipe as a casing material for the well which uses predominantly local materials and local labor. Galvanized iron piping is expensive and harder to handle than bamboo. If bamboo is kept from drying out, it can outlast cast iron which tends to rust and corrode.

Several nearby tubewells can be served by a single diesel pumpset transported between sites by bullock cart or by an animal-driven pump. In the Kosi region of Bihar state in India, over 60,000 bamboo tubewells were installed from 1970 to 1980. Nearly 60% of the irrigated land in that region was served by a bamboo tubewell.

The bamboo tubewell is a good example of an induced innovation. It was developed because small farmers could not afford the high cost of irrigation by conventional wells. The cost savings from this technology is due to (1) lower drilling costs, (2) cheaper casing materials, and (3) elimination of concrete/masonry channels. The technology has spread in India through a combination of private sector contractors, user initiative, and a limited amount of government support.

Rural Access Roads. In the mid-1970s, Kenya began a rural access roads program that emphasized labor-intensive construction methods. As of early 1984, over 7,000 kilometers (km) of roads had been completed under this program. Themain operations in road construction are earthworks, production of aggregates, and surfacing. Labor-intensive methods are most suitable for earthworks. Earthworks comprise over 50% of conventional road building costs and include such activities as the removal of vegetation and boulders to clear a right of way; and the excavation, loading, hauling, spreading, and compaction of soil. Domestically produced hand tools such as hoes, shovels, picks, pangas, and rakes are used. The techniques were adapted to be simple and to use survey pegs, tapes, string lines, camber boards, and levels instead of theodolites. They also eliminated the need for an expensive, imported bulldozer with a crew of three skilled workers. The total costs per kilometer of road were $7,200 by the labor-intensive method, compared to $8,300 by the

by the labor-intensive method, compared to $8,300 by the conventional method. In addition, the labor-intensive techniques provided employment for 200-300 unskilled, local laborers.

Kenya has also adopted a labor-intensive strategy of road maintenance called the "lengthman system" as a replacement for the previous approach of relying on temporary, mobile work crews. A lengthman is a former construction worker who is responsible for maintaining a 1.7 km stretch of the road surface, shoulder, drains, and culverts. Lengthmen are paid for 12 days of work per month and are provided with the necessary hand tools.

The Kenyan rural access roads program has been successful because of technical support and close supervision of workers through a decentralized management system. The program relies heavily on trained paraprofessionals because of a shortage of engineering graduates. It showed that the most economically efficient alternative for road construction can also be the most socially desirable in terms of employment. Popular support for the program is high because workers are hired from the vicinity of the roads, and local institutions for decision-making are involved in the selection of workers.

Cooperative Pappad Processing. Pappad is a traditional, Indian unleavened flat bread made of lentils and flour. Lijjat Pappad is a successful women's cooperative that produces and distributes this product for domestic consumption and export. These pappads sell at a premium price because of their high quality. The innovative element in this case is the production and distribution system rather than the technology for making pappad. This cooperative began in 1959 with 7 members. By 1980, there were over 6,000 members of the cooperative and gross sales exceeded $3.4 million.

The ingredients for making pappad are bought in bulk and ground at a mill in Bombay owned by the cooperative. Then, the ingredients are transported to the 21 cooperative centers where they are combined using hand mixers, formed into large balls of dough, and weighed. The dough balls are distributed to coop members daily. The coop members use simple, hand equipment at their homes to roll the dough into flat, round sheets before leaving them to dry in the sun. The next morning, the finished pappads are brought to the cooperative centers for a quality control inspection, packaging, and transport to marketing agents.

The women receive payment by piece rate. The average daily cash earnings from this part-time work at home are higher than comparable alternatives because of the cooperative structure. In addition to the immediate earnings, there is a

compulsory savings plan and a profit-sharing arrangement. The marketing agents are paid by commission and there are no credit sales.

What are the reasons for the success of this cooperative? Pappad production is well-suited to a combination of light industrial and home processing. The product is appropriate for consumers in most income groups in a wide geographic market. The workers receive a fair payment by local standards and have an incentive to expand output. Lijjat has avoided the usual government marketing outlets for cooperatives in favor of private marketing agents who have an incentive to increase sales. The production system minimizes working capital requirements and the cash basis reduces cashflow problems. Quality control has been maintained well.

The cooperative has a sound commercial orientation. In the early years, it financed most of its own expansion although it has now obtained credit lines from the government village industries commission. The cooperative also has a democratic, decentralized structure with elected officials and appointed managers who have risen from the ranks of pappad makers. All of the members are women and each has the status of a partner rather than an employee. The cooperative is now diversifying into other products.

Small Farm Implements. The Themi Farm Implements and Engineering Co. is a private, profit-making firm that is successfully producing and selling equipment appropriate for small farms in Tanzania. The firm was started in 1982 with loans and technical assistance from the AID-funded Arusha Planning and Village Development Project (APVDP). A group of young engineers and businessmen joined together as partners and provided a 15% equity share. Themi began by concentratingon two products: (1) wooden oxcarts in complete or kit form and (2) metal toolbar-plow sets. In 1983 and 1984, it produced 40 complete oxcarts, 1,162 sets of oxcart wheels, 628 sets of oxcart axles, 23 sets of oxcart tires, 600 plows, 1,533 plowshares, and 210 plow wheels. Themi also produced various attachments for plows such as cultivators, harrows, ridgers, and planters. Despite Tanzania's 30% inflation rate, many of Themi's current ex factory prices are substantially lower than the pre-1984 prices because of efficiency gains in production.

The oxcart is based on a standard design developed by a government research workshop, then known as the Tanzania Machinery Testing Unit (TAMTU). Based on its field testing, Themi found that most farmers in the region preferred a lighter channel design over the TAMTU pipe design because of the predominantly clay soils.

The toolbar/plow set is based on a design adapted at Makerere University in Uganda in the 1960s from the UNIBAR design of a British firm, A. R. Stokes. Themi made further improvements

in its design by substituting a depth wheel for the depth bar, including a height adjustment mechanism for the handles, adding more weeding tines, and strengthening the draw and hitch system.

This equipment is appropriate in rural Tanzania because there is a shortage of agricultural labor during the limited planting and harvesting periods. Small farms in Tanzania often have unused arable land. By increasing the productivity of this labor, the equipment allows an expansion of the land area under intensive cultivation. Some farmers also earn extra income by renting oxcarts to their neighbors.

The APVDP emphasized the creation of self-supporting regional enterprises such as the Themi Company instead of the previous strategy in Tanzania of concentrating on parastatal R & D workshops. The new entrepreneurs were willing to take necessary risks and some of the partners had prior experience in manufacturing similar or related products. Before beginning production, Themi carried out a market survey for the region. Later, as the market for oxcarts became saturated, Themi changed its production mix. The workers were given bonuses for exceeding targets.

Following Themi's success, other firms entered the small farm equipment market in other regions of the country. Themi has sustained its profitability in the face of competition by maintaining a reputation for high quality products at low cost, diversifying into other products, and providing jobbing services for other small industries. The project took place at a time when government agricultural policies became more favorable to small farmers, stimulating investment. Most farmers in the region already had a tradition of using draft animals and the government extension service offered free training on their use.

In-depth Case Studies

As a follow-up to the short case studies, ATI prepared four in-depth case studies on: (1) manual pumps in Bangladesh, (2) bamboo-reinforced concrete rainwater storage tanks in Thailand, (3) grain storage bins in Central America and (4) fuel-efficient charcoal stoves in Kenya.

Manual Pumps. Darrow (1985) reports that at least 55,000-116,000 manual pumps (hand- or foot-operated) are in use for irrigation in Bangladesh, each serving an average of 0.5 acres of land. Nearly all of them are less than 12 meters (m) deep. The three main designs of manual pumps are the cast iron "New No. 6 pump", the "treadle pump", and the "rower pump".

The cast iron, No. 6 pump is familiar, having been used in the country for drinking water over 60 years. It was not

designed as an irrigation pump, but is capable of lifting relatively large quantities of water and is durable. The installed cost is about $75 per pump. The cast iron, manual tubewells are dug up each year to prevent theft and to improve the water yield though resinking of the well elsewhere. Spare parts for the pump are available in local markets and many owners can do the repairs themselves.

The No. 6 pump has been disseminated for irrigation purposes in Bangladesh since 1974 through large-scale, subsidized programs of UNICEF, AID, and the World Bank. By mid-1984, about 200,000 No. 6 pumps had been distributed under these programs, but most were being used for drinking water rather than irrigation (the estimates range from 57 to 88% for drinking water). These pumps were distributed through cooperatives that tended to reach middle-income farmers who often preferred to use them for drinking water or resold them to small-scale farmers.

The steel and bamboo treadle pump is conveniently operated by foot. It is inexpensive with an installed cost about $20, but the bamboo deteriorates rapidly so a support network for repairs is needed. This pump is only usable where the water table is high enough so that a total lift of less than 5.5 m is required. These pumps are made in private, roadside workshops under contract to the Rangpur-Dinajpur Rehabilitation Service, which sells them to farmers. The treadle pump was developed 1980 and about 25,000 were in use as of late 1984.

The rower pump is a direct action, piston suction pump developed in 1980 under the auspices of the Mennonite Central Committee. It has only one moving part, a piston, which can be easily removed for safekeeping or repair. This design is well-suited for moving a large volume of water over a small lift. The performance of the standard rower pump is best with lifts less than 7.6 m, but the diameter can be modified for deeper water table conditions. The installed costs are $40-60, depending on the depth of the well and whether the well casing is made of bamboo or plastic. The polyvinyl chloride pump cylinder is attached to a tubewell at an angle, allowing the operator to pump through rowing motions of the arms while in a standing or sitting position. This innovation makes the pump easier to use than conventional handpumps because a larger volume of water is lifted with each stroke. It also reduces maintenance requirements because it places less stress on the body of the pump. The rower pump is made at the Mirpur Agricultural Workshop and Training School in Dacca, with some parts subcontracted to small workshops. About 5,000 were in use as of late 1984. The pump itself is sold through local dealers at a relatively unsubsidized price, but the Mennonite Committee subsidizes installation costs.

Manual handpumps filled a demand in Bangladesh. In fact, it was farmers rather than agricultural researchers who first used the handpumps for irrigation. Handpumps can significantly increase the value of agricultural production during the dry season. Intervention by an outside organization was necessary to finance the R & D work because local entrepreneurs could not bear the costs and risks of developing a new design. Outside technical assistance brought in knowledge about work that had been done elsewhere. The smaller-scale programs were able to concentrate on design innovations because they did not begin with a nationwide dissemination effort to meet high distribution targets. Thorough field testing of the technology was important because it led to design modifications that helped ensure the acceptability of the pump to users.

Careful attention was paid to quality control in production of the treadle and rower pumps. Once the rower pump was demonstrated and early promotional efforts carried out, the market proved to be a cost-effective means of disseminating the technology. Under the smaller-scale dissemination programs, there was less displacement of the pumps from irrigation to drinking water purposes, and a larger share of the pumps reached small farmers.

Rainwater Collection and Storage Tanks. Approximately 25-30% of households in Northeast Thailand do not have year-round access to good quality drinking water. Northeast Thailand is the country's least developed region. The region has a 6-7 month dry season and the predominantly sandy surface soils retain water poorly. Since there is abundant rainfall during the rainy season, the region has a good potential for collecting and storing rainwater for use in the dry season (Fricke 1986).

Other ways of solving the water supply problem had been attempted earlier. Several government agencies have been providing free drilling equipment, mobile teams, and pumps for tubewells to villagers. However, the tubewells program has encountered some difficulties: (1) a large number of the pumps (18-50%) are inoperative because villagers have not maintained equipment that they perceive as belonging to the government; (2) poor performance or short life of the wells as a result of improper siting and installation; and (3) high mineral content in the local groundwater. Piped surface water systems only serve 4% of the region's population, and much of this water is being used for irrigation rather than drinking because many villagers dislike the taste of chlorinated water.

A national NGO, the Community-Based Appropriate Technology and Development Services division (CBATDS) of the Population and Community Development Association (PDA), has been very effective in disseminating rainwater collection and storage systems in the region. By the end of 1984, 7,000 large,

bamboo-reinforced concrete cisterns ("tungnam") and over 5,000 small, wire-reinforced concrete mortar jars had been installed by CBATDS. Following the lead of CBATDS, government agencies have distributed about 2,000 cisterns and 40,000 mortar jars in the Northeast region.

Rainwater catchment from the roof of a house may be channeled to the cisterns or mortar jars through folded, galvanized iron sheets; split bamboo troughs; or metal gutters fixed under the eaves. A household in Northeast Thailand with 6 or 7 people would require 5-8 cubic meters (cu. m) of drinking water during the dry season.

The cisterns are cylindrical tanks that were designed at Khon Kaen University in the early 1970s. Each cistern is built at its site over a concrete base. A mesh of split bamboo serves as a low-cost reinforcement to reduce stress on the base and walls of the structure. Temporary metal forms are used as a 1:2:3 mixture of cement, water, and concrete is poured over the reinforcement. Other features include a plastic, foul flush device between the gutter and the tank inlet, and a faucet with a locking mechanism to prevent leaks and thefts. The foul flush device should be cleaned each year. The shell of a cistern can be built in a day, but about 36 laborers are required because of the large bulk and weight of materials. The most common size for a household cistern has a capacity of 11.3 cubic meters. This capacity may be larger than necessary for an average household, but it includes an allowance for larger families, visitors, and possible construction flaws. The materials for a cistern cost $150. A cistern should last 20 years if properly constructed. However, if the mesh is exposed, it may be attacked by termites. The concrete walls must be thick enough to prevent cracking. Their strength also depends on the proper mixture of cement and allowing sufficient time for curing. Some improvements on the design and materials composition of cisterns are being developed.

Mortar jars resemble the traditional technology for water storage (uncovered clay jars with a 0.2 cu. m capacity which cost $8.50). However, the mortar jars are larger and have a metal lid and a tap or drainage valve to prevent contamination. These jars can be easily made by local artisans using cement, sand, and galvanized sheet metal. Since a mortar jar typically holds 2.0 cu. m of water, a household would need 3 or 4 of them. A mortar jar should last 15-20 years. One mortar jar currently costs $18.50-$22.00, including transport. Due to increasing competition with the entry of new small producers, the price has fallen from $23.50-$30.00. Many rural households can afford the current price without credit. Per unit of water stored, the mortar jars are cheaper than the traditional ceramic pots.

Prior to 1980, the mortar jars were only being produced by one large cement company. Since then, a sizable number of

small, informal sector workshops with 5-30 workers have begun production of mortar jars in the region. Unsubsidized sales of the mortar jars on the private market have proceeded in parallel with donor-funded programs that have provided loans or a small subsidy for cash purchases. No private companies are building the cisterns because few households can afford them without credit. In addition, there are few economies of scale in production of the cisterns because they are built on site.

The early stages of the CBATDS program were funded by ATI. Subsequent funding was provided by the Ford Foundation, IDRC, CUSO, CIDA, and Agro Action of Germany. The CBATDS strategy begins with village meetings and formation of a local committee to select loan applicants and supervise repayment. Self-help production teams of 10-15 people from the community are organized and trained under the supervision of a CBATDS technician. CBATDS offers a 15-year guarantee that it will make the repairs necessary to keep the cisterns operable, and it gives the owner a stamped, addressed card to report any difficulties.

CBATDS sells the cisterns at a subsidized price that just covers materials costs. Purchasers are required to either provide labor for the village team or make an additional cash payment. CBATDS offers 18-month loans from a revolving fund to households interested in buying a cistern. Alternatively, a household may pay cash and receive a 5% discount, but few have chosen to do so because of the low effective interest rate on the loan. Since PDA's largest activity is in programs to reduce population growth, it gives additional discounts to households with family planning acceptors. As of December 1984, 89% of the loaned funds had been repaid on time.

Most of the cisterns disseminated under the government programs have been installed at schools, temples, and local government offices. The Ministry of Public Health offers logistical support and interest-free loans for construction materials, concrete forms and tools. It also gives technical assistance, training, and supervision to village groups willing to provide the labor for cistern construction.

The rainwater cisterns case shows how successful an NGO can be in widespread dissemination of a technology in rural areas. A decentralized strategy with substantial local participation was largely responsible for this success. PDA is an organization with dynamic leadership and a large, dedicated staff at the grassroots level. Although a large portion of the costs were recovered, some subsidization was built into the project, but it probably did not affect the acceptability of the technology very much. Many developed countries also subsidize the supply of safe drinking water to meet public health objectives. The approach adopted in this case involved less subsidization than the alternatives of developing centralized or large-scale groundwater or surface

water delivery systems. In addition, the maintenance costs for rainwater collection systems are very low and there usually is not a long down time for repairs. Nevertheless, it would have been more cost-effective to promote the small mortar jars instead of the large cisterns.

Grain Storage Bins. Large quantities of grain can be lost to spoilage and vermin during storage. Yet, if small farmers do not store grain, they are forced to sell it at harvest when the price is lowest rather than holding it for sale or subsistence in subsequent years when it might be in shorter supply. Simple, family-sized metal bins have been used for grain storage in Central America since the early 1900s. The exact origin of this design is not known, but is thought to be El Salvador or Guatemala (Fricke and Granovsky 1985).

The bin is made of galvanized metal soldered into a cylinder with a flat bottom and conical top. The most common size has a storage capacity of 1 tonne and costs about $35 in Central America. The bins are portable. Some of the bins have two metal bands around them to reinforce the sides, but this could cause oxidation problems. A bin should last at least 15 years under typical conditions and could last as long as 25-40 years if well built and maintained.

The bins keep grain clean, dry, and cool to reduce spoilage. They are best suited for maize, sorghum, and beans. With proper management, the bins also reduce losses from birds, rodents, insects, and microorganisms. Before storage, the grain should be sorted, dried, and cleaned. Although the bins are not hermetically sealed, it is generally recommended that a fumigant such as carbon disulfide or hydrogen phosphide be added to kill insects when the grain is first placed inside. Some concerns have been raised about these fumigants if they are mishandled. A bin should rest on some support and be put in a shady place away from walls to allow air circulation around the outside of the bin. If properly managed, the grain could last for several years, but most farmers only store it for 9-12 months. If poorly managed, grain losses in the bins could exceed those from traditional storage methods such as bags, drying cribs, or wooden bins.

About 150,000 of these bins are currently in use in El Salvador and 100,000 in Guatemala. During the last few years, a few thousand bins have been introduced in Honduras and two dozen or so in Costa Rica. Small-scale farmers in Costa Rica have less of an incentive to store grain because a national grain storage agency maintains stable domestic prices for grains.

This case study is an example of spontaneous replication through the private sector. Widespread dissemination of the bins in El Salvador and Guatemala largely occurred through small-scale artisans who sold them directly to farmers

without any government subsidies, technical assistance, training, or extension support. In the mid-1940s, rural credit agencies in El Salvador did allow financing for the bins as a component of larger loans. During the mid-1960s, U.S. AID also supported a revolving credit fund for grain storage bins in El Salvador.

Recently, the Swiss Cooperative Development Group has offered training, subsidized credit, and assistance with raw materials supply to individuals in Honduras interested in making grain storage bins. AID has provided start-up financing to three small workshops in Honduras that make these bins and unsubsidized credit to farmers under a small farm technologies project. The limited number of bins in Costa Rica were introduced as one small part of broader research and demonstration projects.

The grain storage bins have spread spontaneously in El Salvador and Guatemala because they provide financial benefits and security for small farmers, and small-scale artisans can earn enough profit making them along with other metal products. Small farmers in Central America produce enough surplus grain to make on-site storage feasible and they understand the benefits of the technology. The payback period for a bin is generally less than one year. New galvanized metal is sufficiently available in rural areas in Central America at a reasonable price, and the artisans have passed the necessary skills on to their relatives or apprentices. ATI has brought this technology to the attention of a technology development organization in Tanzania where it is unknown.

Improved Charcoal Stoves. Efforts at promoting fuel-efficient charcoal stoves to replace traditional charcoal stoves in Kenya have been much more successful than most of the improved woodstoves projects throughout the world. As of the first quarter of 1985, over 84,000 of these stoves have been purchased by consumers (Hyman 1985). Since charcoal is a marketed fuel, users have a financial incentive to conserve it, unlike wood which is often collected for free. The Kenya program, funded by AID, was successful because the ceramic-lined and insulated design built on the traditional all-metal stove. The improved stove does have a different shape (bell-bottomed instead of cylindrical) that allows it to be easily recognized. It also has a fired ceramic lining and a layer of cement/vermiculite insulation that fixes the lining in place within the metal cladding. The design was extensively field tested and modified as a result.

The improved stove costs about $4.00 while the traditional stove costs $2.50. However, at full use, the improved stove should last for 2-3 years while the traditional stove only lasts for 1 year. Accounting for the initial costs, periodic replacement of the liner for the improved stove and the grate for the traditional stove, replacement of the whole stove as

it wears out, and the charcoal savings, an average Nairobi household would save about $31 over a two-year period by replacing a traditional stove with an improved stove.

Production and distribution of the improved stoves involved existing informal sector artisans who have low costs and a profit incentive. Decentralized support was provided to these artisans including training and demonstration to potential consumers. This relatively unsubsidized approach proved much more effective than the cumbersome dissemination strategy of user-built stoves tried elsewhere.

Case Studies of Less Successful Attempts

ATI has also examined the lessons learned from less successful attempts at disseminating what were thought to be appropriate technologies. Two such examples include ferrocement fishing boats on Lake Malawi and a fiber-reinforced roofing sheets technology.

Ferrocement Fishing Boats in Malawi. Ferrocement is a mortar of cement, sand, and water that is densely reinforced throughout with steel mesh wire and formed into a thin shell. It has several advantages as a boatbuilding material. Suitable timbers for boats are becoming scarcer in some countries. A ferrocement boat can have a longer life than wood and is resistant to fire, termites, and borers. It can be formed into complex curves that improve boat performance and it easily accommodates stresses from loads and alternate heating and cooling or wetting and drying. Ferrocement boats are much cheaper than steel or fiberglass and require less imported material. Construction of a ferrocement boat is labor-intensive, but it demands less skilled labor than for a wooden boat.

Although large numbers of ferrocement boats are in use in less developed countries, particularly in the Asia-Pacific region, ferrocement sail boats with engines for supplementary use did not prove to be appropriate for Lake Malawi (Hyman 1986). This happened even though the project supported by ATI used an innovative construction method that allowed ferrocement boats as small as 5.6 m in length to have a sufficiently low weight. Previously, 7.6-9.1 m was considered to be the smallest feasible size. Nevertheless, this boat size is still too big for private fishermen on the northern shore of Lake Malawi. About 99% of the fishermen there are now using simple dugout canoes with oars and only only 1% are using wooden plank boats with paddles or an outboard motor. A ferrocement boat would allow these fishermen to go farther from the shore of the lake to exploit resources and to fish more days per year when weather conditions are too hazardous for canoes.

Although financing was available for purchase of a ferrocement boat and a commercial analysis showed that it could be profitable, it requires a high level of fishing effort and management ability that is lacking in the area. Government price controls on fish also reduced the demand for more intensive fishing technologies. In addition, there was a negative demonstration effect from a defunct, earlier project that built poor quality ferrocement boats of a different design. The more recent project did find out that there is a good potential for adding sails to dugout canoes and wooden plank boats. The weather conditions are suitable for this; there is just little tradition of sailing in Malawi unlike the Mozambique-controlled portions of the Lake.

Fiber-reinforced Roofing Sheets. The Intermediate Technology Building Materials Workshop has promoted the use of fiber-reinforced concrete sheets as an inexpensive roofing material for low-income housing. This material consists of sisal or coconut husk fiber (coir) mixed into portland cement, water, and well-graded sand. The mixture is spread into a simple frame on a plastic sheet and trowelled flat. Then, the frame and plastic are removed, allowing the mortar to take the shape of the corrugated former under it. Primary curing of the roofing sheet in the mold takes 24-72 hours, followed by secondary curing (2 to 4 weeks of sprinkling with water several times per day or 1 week under submerged conditions).

ATI and the Save the Children Foundation sponsored several demonstration projects to test this technology. These projects showed that the product, as it is usually made in practice, is not sufficiently durable. As much as 50% of the fiber cement sheets in Colombia had visible cracks within 1 year. Workers found it difficult to produce a mix with the correct proportions by hand, and to follow adequate procedures for casting and curing. With careful production and installation, experience in Sri Lanka shows that the cracking rate can be reduced to 10% for smaller and thicker sheets. Nevertheless, the production of fiber cement roofing sheets requires more worker skill and quality control than is common in villages in most less developed countries, and poor installation practices increase the cracking. Attempts to repair the cracks proved unsuccessful.

Moreover, fiber-reinforced cement sheets become brittle under the weather conditions of the humid tropics. A technical study has shown that the alkalinity of pore water in the cement tends to dissolve the fibers, accelerating decomposition. The flexural strength of the material also deteriorates over time, causing it to bend from its own weight. In practice, the fiber-reinforced cement sheets have lasted 2 to 4 years, compared to 12 or more years for galvanized iron sheets. Although the initial cost of fiber-reinforced cement roofing sheets can be 30-50% lower than galvanized iron roofing materials, the total costs including

replacement are much higher for fiber-reinforced cement sheets. Since a large number of households cannot afford the higher initial cost of galvanized iron, there is still a need to develop a better, low-cost alternative.

The Macro-policies Study

ATI commissioned a set of ten studies on the effect of macro-level policies on the potential for adopting appropriate technologies. These studies cover the following topics: (1) classification of macro-policies, (2) technology choice in agriculture in India, (3) irrigation technology in Bangladesh, (4) small-scale paddy threshing in Thailand and the Philippines, (5) rural linkages in the Philippines and Taiwan, (6) small-scale sugar manufacturing in India and Kenya, (7) technology choice in public enterprises in Kenya and Tanzania, (8) in-plant technical change in Latin America, (9) the standardization of machine tools in Japan and China, and (10) an overview and conclusions for the set of studies.

A Classification of Macro-policies

Decisions on the adoption of technology are made by firms at the micro level. These decisions are based on the (1) objectives of the firm, (2) resources available to the firm and relative prices, (3) size and type of the market, and (4) knowledge of what technologies are available. Stewart (1986a) emphasizes that government macro-policies can have a large effect on the above micro-level factors through overall economic conditions (e.g. the money supply, interest rates and the availability of credit, aggregate demand, currency exchange rates, and the distribution of income), direct public expenditures (including investments in infrastructure or enterprises, human resource development, subsidies, and tax preferences), and regulations (especially those pertaining to wage rates, the transfer of technologies, foreign investment and trade, and the size-composition and ownership of economic units).

In some cases, technologies with low or negative social benefits persist because of inappropriate macro-policies. Government policies are influenced by varying degrees by interest groups. The government itself is not monolithic, but is composed of agencies and individuals with different interests. Current options may be limited by past decisions. Governments and multinational corporations also play a direct role in R & D and the choice of technologies. R & D tends to concentrate around the types of technologies and products currently in use.

Technology Choice in Agriculture in India

Rudra (1986) argues that India had adopted appropriate agricultural policies immediately after independence, but switched to what he feels are the inappropriate policies of the Green Revolution in the 1960s. His definition of appropriateness emphasizes distributive justice, participation by the local people, employment, use of local resources instead of imports, and degree of foreign influence. During the post-independence period, government policy statements urged the restriction of large-scale mechanization to wastelands, the improvement of hand and animal-drawn farm implements, the selection and certification of seeds, the use of organic fertilizers, and the construction of minor irrigation works.

The Green Revolution did bring about substantial increases in production of major foodgrains in India for domestic use, export, and stockpiling. However, he asserts that total agricultural output could have been at least as high or greater if subsidies and improved inputs had been thinly spread over all farms rather than being concentrated over a few crops on the most favorable sites. Furthermore, unemployment and inequality in the distribution of income and land among farmers could have been reduced within and across regions. The promoted technologies were not scale-neutral because machinery is only cost-effective on larger land areas, and only the better-off farmers could afford large quantities of expensive, purchased inputs. As a result, the higher profits of large-scale farmers enabled them to expand their landholdings by buying more land from the small-scale farmers. In some cases, mechanization had negative net benefits for individual farmers as well as society (Binswanger 1978).

Although serious objections are raised in this paper, it neglects several important considerations. First, it does not consider the consumer's surplus benefits from lower grain prices and the resulting improvement in nutrition and health of the poor. Second, it does not separate out the extent to which the unintended impacts are associated with the Green Revolution technologies themselves or government agricultural policies that are not technology-specific. Third, it does not recognize that small-scale farmers are risk-averse and generally follow the lead of large-scale farmers later after the technologies have been demonstrated. Fourth, it makes no mention of the role of population growth in the increase of poverty and unemployment. Fifth, it is not clear whether the concern over relative poverty is as relevant as absolute poverty as a social indicator.

Irrigation in Bangladesh

The case study on Bangladesh shallow tubewell irrigation which was discussed earlier concentrated on the selection of one of three manual pump designs. Biggs and Griffith (1986) address a larger issue in technology choice for irrigation in the same country--the extent to which manual pumps or traditional low-lift methods should be promoted instead of mechanized pumps. The policies of the government and international development assistance agencies have played a major role in this technology choice.

Traditional, hand-operated irrigation devices (based on leveraged bucket lifting, a swing basket, or a wooden trough and fulcrum) have been used by small farmers in Bangladesh, but they are only suitable for surface water or very shallow wells of less than 1.2 meters. Thus, they do not directly compete with manual pumps.

A manual pump can serve an area of 0.5 acres while a shallow tubewell with a diesel pump can serve 10 acres. If the full 10 acres is served, investment costs per acre are slightly lower for a mechanized pump than for a handpump ($18.50 compared to T.K. 21.00), but this advantage evaporates if only 9 or fewer acres are served. Due to the fragmentation of land holdings in Bangladesh, few farmers have 10 acres of dry season rice to irrigate and most only have 0.5 acres.

Small-scale farmers cannot afford the high capital cost of the mechanized pumps, and irrigation cooperatives in Bangladesh often tend to break down. The fuel and maintenance costs of a mechanized pump serving 10 acres are $3.50 per acre per season, compared to $1.75 for a handpump. However, the mechanized pump only requires 8 days of unskilled labor per acre per season, compared to 160 for the most common handpump design. If this labor is priced at the market wage for casual agricultural labor, the operating costs per acre are also higher for handpumps than for mechanized pumps. Yet, most of this labor is provided from within the household and it may have a low opportunity cost because there are few opportunities for outside employment during the dry season. Moreover, handpumps are not subject to fuel availability problems, are easier to maintain and repair locally, and are more compatible with prevailing hydroclimatological characteristics. Handpumps are also easier to remove and resell if cash is needed.

Before independence in 1971, government policy in Bangladesh favored large irrigation canals and ignored traditional methods or tubewells as alternatives. The results proved slow and disappointing. After 1971, a higher priority was given to mechanized tubewells. Tubewells attracted donor attention because more rapid impacts were expected. Until 1981, most mechanized irrigation equipment was owned by the government and rented to cooperatives at a nominal charge;

thus, private markets for this technology did not develop. The use of traditional irrigation methods declined as they were replaced by mechanized pumps or when the water table dropped because of drawdown by mechanized pumps.

Since 1981, the subsidies for mechanized pumps have been reduced and the Bangladesh Agricultural Development Corporation began selling pumps and tubewells directly to farmers. Due to the scale of this technology and the unequal availability of low-interest financing from government development banks, many larger-scale farmers are buying mechanized pumps and selling water to smaller-scale farmers. As a result, the irrigated area has been increasing rapidly, but the distribution of income in rural areas has become more unequal.

Several policy factors still inhibit the use of labor-intensive irrigation methods that can reach the rural poor. Government agencies in Bangladesh place a lower priority on manual pumps than on mechanized pumps. These priorities may reflect the influence of powerful interest groups within rural society or the commercial sector, or the perception that the most modern technology is best. Mechanized irrigation has been subsidized through prices that are less than the full costs of production, distribution, and installation; low-interest loans; and weak efforts to collect loan repayments.

At the same time, the development of private market channels for cast iron manual tubewells has been hindered by a 50% tax on the imported metal, which is only waived for manual tubewells distributed through government programs. Moreover, research and development institutions have paid little attention to the potential for improving the lifting capacity of traditional irrigation methods. Another important factor is the policies of international development assistance agencies such as the tying of aid to suppliers from the donor countries, and the financing of foreign exchange and capital costs rather than local or recurring costs.

Paddy Threshing

Threshing is the process of beating grain from its husk. Winnowing then separates the grain from the chaff. Compared to a small-scale mechanical thresher and winnower, the traditional means of threshing and winnowing rice manually are slow and waste grain (Duff 1986). The traditional methods of threshing paddy in the Philippines are by foot treading or hand beating over a platform. In Thailand, rice is threshed by driving a water buffalo or a tractor over the grain, and it is winnowed with a basket or wooden fan. Large, mechanical threshers similar to the old, McCormick stationary thresher from the United States have been used on some large estates in the Philippines since the 1920s. These

machines have a low grain recovery rate and require a large amount of labor in collecting and stacking the paddy. Following land reform, they are no longer widely used and there has been a return to the tradtional methods.

The International Rice Research Institute (IRRI) began development of a small, low-cost, rice threshing and winnowing machine in 1967. Work focused on axial flow designs starting in 1970. In 1974, IRRI provided an axial thresher design with a capacity of one ton per hour to small manufacturers in the Philippines. After field tests indicated a demand for a lighter, more mobile unit in the Philippines, a portable version was developed in 1976. By contrast, the larger model is more popular in Thailand. The portable machine sells for about $1,000 while the larger versions sell for up to $2,500.

The IRRI thresher has several advantages. It can handle wet grain and has a high separation efficiency. The thresher can be easily manufactured by workshops in developing countries because it does not require any special materials and has no complex parts. The design has been modified to make it easier to clean and more efficient, and to facilitate its use for threshing wheat and corn as well as rice.

At least 79 small firms in the Philippines and 30 larger firms in Thailand are producing the thresher as participants in the IRRI program. The participating firms had produced about 55,000 threshers by 1984. In addition, half again as many firms have spontaneously begun production of the thresher in these two countries. The design has spread to other countries as well. In 1985, over 200 manufacturers in 18 countries were producing these threshers.

The impacts of this technology differ between the two countries and even across regions within the countries. Farm sizes tend to be larger in Thailand than in the Philippines. The thresher increases the incomes of small and medium-scale farmers and reduces labor supervision problems. Small-scale farmers can hire the services of the IRRI thresher from larger farmers and nonfarming contractors. Over 70% of the farmers who have purchased these threshers did not need credit to buy them. Between 40-45% of the purchasers in the Philippines and Thailand do not own any land and bought the threshers as a source of income from contract work.

However, post-harvest mechanization may have negative impacts on hired farm labor and on the traditional rights of gleaners to collect what was left behind in manual threshing (as much as 10% of the crop). The mechanical thresher reduces postharvest labor requirements by 20-25%. Labor for peak agricultural periods is in excess supply in the Philippines, but is in relatively short supply in Thailand where uncultivated, arable land is still available. Unlike Thailand, the Philippines has a large and growing landless

population in rural areas. Most of the impact of postharvest mechanization has been on hired labor in the Philippines. Half of the displacement in Thailand has been absorbed by unpaid household labor, which sees this as a reduction in drudgery. Some of the displacement is offset by the extra labor needed for processing the increased net yield of rice because the mechanical thresher reduces rice waste by 1-6%, and some labor is employed in manufacturing the thresher. Accounting for all of these effects, the mechanical thresher has reduced agriculture-related employment by about 7%. Since real wages in all sectors, including agriculture, have fallen in the Philippines and generally risen in Thailand, it is difficult to attribute any changes in farm wages to introduction of the thresher.

The social impacts of displaced hired labor are serious because they fall on the unskilled or the landless poor. However, it should be noted that traditional systems of distributing shares of the rice crop are breaking down in many areas due to the monetization of rural economies and social changes apart from mechanization. Increasingly, labor is paid through daily cash wages rather than a fixed share of the crop and gleaners are losing their traditional rights.

The conventional economic view on labor displacement is that technical change that results in unemployment should not be avoided where the total gains to society exceed the losses to the displaced individuals. Nevertheless, the adverse distributional impacts should be mitigated through efforts to develop more productive sources of low-skilled employment in rural areas and to provide training so that displaced workers can fill these jobs.

The IRRI program resulted in the dissemination of large numbers of threshers because it relied on existing workshops that were given technical assistance and designs that met a local demand. It is unlikely that the R & D work needed to bring this about would have been done by the private sector although once a basic design was available, local manufacturers made further refinements. The returns to this investment are high for the owners of the machines and the farmers who hire them, particularly with irrigated paddy.

Public policy within the two target countries had little direct effect on the adoption rate for this technology. World Bank-financed credit was available in the Philippines for tractors, but not for threshers. The Thai Government has taken a laissez-faire approach to small farm mechanization. General policies affecting the profitability of agricultural production and wage rates may have had some indirect effect.

Rural Linkages in the Philippines and Taiwan

The amount and nature of expansion in the agricultural sector has a strong effect on other rural economic activities through backward, forward, and consumption linkages. Backward linkages are changes in the profits of local industries supplying inputs to agriculture. Forward linkages pertain to local industries that process agricultural products. Consumption linkages from the respending of income earned in farming may increase the profits of local producers and sellers of various goods and services. Although it is difficult to measure and attribute causality for linkage effects, theoretical grounds and empirical evidence support the claim that appropriate technologies generate more linkages in the rural economy. Because Taiwan and the Philippines have pursued different development strategies, the resulting linkages in rural areas have been very different in the two countries (Ranis and Stewart 1986).

Many aspects of the economies of Taiwan and the Philippines were similar in 1960 (e.g. per capita income, the agricultural share of the Gross Domestic Product (GDP), exports relative to GDP, adult literacy, and educational enrollment ratios). Some aspects were better in Taiwan (e.g. gross investment as a share of GDP, life expectancy, and equality of land distribution) while others were better in the Philippines (e.g. income equality and median farm size). Expenditures on public services were higher in Taiwan.

Since then, the two economies have diverged because different development strategies and policies were adopted in each country. Between 1960 and 1980, per capita income grew at 6.9% per year in Taiwan and only 2.8 % per year in the Philippines. Both countries experienced comparable growth rates in agricultural production. However, agricultural labor productivity, industrial employment, nonagricultural rural employment, industrial labor productivity, and exports of processed goods grew at a faster rate in Taiwan.

The Philippines had emphasized policies favoring centralized production and import substitution such as high tariffs and subsidized interest rates. By contrast, Taiwan had emphasized decentralized production and exports in an open economy with realistic factor prices. Investments in rural infrastructure development were higher in Taiwan, particularly for electricity, piped water, paved roads, and railroad transportation. There were other differences in cultural attitudes and organizational structure as well.

In general, the technologies used in rural areas in both countries have been less capital-intensive, smaller-scale, more self-reliant in the use of local materials, and more oriented toward appropriate products than those adopted in urban areas. The main source of this growth was from consumption linkages (including public services).

Consumption linkages accounted for two-thirds of the increase in rural nonagricultural employment in Taiwan and four-fifths in the Philippines. However, as agricultural production increased, the largest percentage increase was in forward linkages. Although forward linkages created more rural employment than backward linkages in both countries, backward linkages were relatively more important in Taiwan than in the Philippines. More rural industries that were not linked to agriculture developed in Taiwan.

As average farm income increases, nonagricultural income in rural areas tends to rise at an even faster rate. Consumption linkages are higher when the farm income gains are equitably distributed because high-income households save more of their income and consume more goods that are produced in urban areas or are imported while low-income households spend more on food and locally produced goods. The distribution of agricultural income is affected by the size-composition of farms, labor-intensity of the technologies used, and nature of the market for the crop.

The backward linkages in the Philippines have mostly been confined to sales outlets for fertilizer, seeds, and machinery. Farm equipment servicing and manufacturing was a more significant source of employment in Taiwan. Backward linkages tend to be larger if farmers use small-scale equipment and implements that can be produced in rural workshops such as power tillers, portable threshers, handpumps, plows, harrows, and hand tools. The use of small-scale, mechanized equipment grew rapidly on Taiwanese farms in the 1960s due to a comparative shortage of labor. In the Philippines, government policies promoted large-scale tractors despite the abundance of unskilled labor and the slight effect of this technology on crop yields. The most significant of these policies in the Philippines was the availability of subsidized credit for tractors. A net implicit tariff of 0% on tractors compared to 19% on power tillers was also important.

Forward linkages in rural areas from agriculture have been much larger in Taiwan than in the Philippines because of the greater decentralization of the food processing industry in Taiwan. Specialty vegetables that are very perishable are processed for export in rural areas in Taiwan; these products are not major exports of the Philippines. The structure of the fruit processing industry differs in the two countries.

There are a large number of pineapple processing companies in Taiwan and many of these companies have several dispersed canning plants. Pineapple processing in the Philippines is dominated by a small number of multinational firms with a few, large, capital-intensive plants. The Taiwanese product does not have recognized name brands and its quality is uneven because the pineapple is purchased from a large number of small farmers. Nevertheless, Taiwan has continued to be a

successful producer because it has filled a cheaper segment of the export market and the domestic market. The Philippine product is of higher quality, but production costs are higher due to the minimum wage laws and the relative lack of rural infrastructure, which has raised capital costs and encouraged centralization of facilities around company-owned plantations.

Dispersed farming by smallholders and decentralized processing has not been as successful for the banana industry in Taiwan. It has been unable to compete with the plantations of multinationals in the Philippines because the principal market, Japan, requires a high-quality product which is dependent on large-scale systems of packing, transport, refrigeration, and advertising to build brand loyalties.

Forward linkages from rice processing are very important in the Philippines. The most efficient method of drying rice is by sun-drying rather than mechanical means. Mechanical threshing is much cheaper than manual threshing unless household labor has no opportunity cost.

A range of technologies are available for rice milling: a steel huller, a steel huller with rubber-rollers, and a cono mill. Each of these types of mills has a similar recovery rate, but ordinary steel hullers leave more broken rice. The steel huller has the lowest capital costs. The large-scale cono mill has the highest capital costs and offers no advantage in operating costs. At typical capacity use rates, the steel huller is most appropriate for village mills processing rice for local consumption. The steel huller with rubber rollers is most appropriate for commercial processing for urban consumption and export. However, government policies in the Philippines, with Asian Development Bank support, have encouraged the establishment of large-scale, integrated rice processing plants with large threshers, mechanical driers, and cono mills.

Ranis and Stewart recommend the following policies to encourage rural development: (1) increasing agricultural production to foster linkages; (2) carrying out land reform; (3) ending subsidies for mechanization; (4) encouraging high-value, labor-intensive crops; (5) developing productive and social infrastructure; (6) allocating more credit to rural and small-scale activities; and (7) providing technical assistance and other support to small-scale producers.

Small-scale Sugar Manufacturing

A medium-scale, labor-intensive technology for sugar manufacturing, the "open pan" (OP) process, can be a viable alternative to the large-scale, capital-intensive "vacuum pan" (VP) process (Kaplinsky 1986). The older OP process evaporates water from cane juice through boiling in open

pans. The VP process reduces the boiling point of the juice by increasing the pressure. This boosts the yield of sugar crystals by avoiding the production of invert sugars which are dissolved in molasses. The typical capacity of a sugar mill is 1,250 tonnes of cane per day (tcd) for a VP plant in India, 7,000 tcd for a VP plant in Kenya, and 100-200 tcd for an OP plant.

Until 1982, the OP process had a serious disadvantage which made its production costs uncompetitive--a low crystal sugar recovery rate of 7.2%, compared to 9.5% for the VP process. As a result of R & D work in India, the recovery rate for an OP plant has been raised to 8.1% and the labor and fuel requirements have been reduced. The OP process does produce a darker colored and unevenly granulated product which sells for 10% less than VP sugar in India, but about the same price as VP sugar in Kenya. Considering a new plant or basing the depreciation of an old plant on replacement costs rather than historic costs, the production costs per unit of output for a 200 tcd OP plant are 16% lower than those for a 1,250 tcd VP plant in India and 34% lower than those of a 7,000 tcd VP plant in Kenya.

In addition, an OP plant generates substantially more employment than a VP plant. If the domestic sugar demand were met by 200 tcd OP plants rather than VP plants, employment in the industry would increase nearly 200% in India and 500% in Kenya. An OP plant can also be placed on line much faster and can tap smaller, local producers for cane. Both types of plants are produced domestically in India, but only OP plants are fabricated in Kenya. Foreign exchange costs are much higher for a VP plant. The disadvantages of the OP process are that the output is only suitable for domestic markets and more land would be required for cane production for the OP process.

Technology choice in sugar manufacturing has been strongly affected by market-distorting policies. Government decision makers and donors often favor highly visible, large enterprises over small, decentralized enterprises. Most sugar mills in Kenya operate under management contracts with foreign firms that are most familiar with the VP process. Because large-scale sugar farms are often owned by or contractually tied to VP mills, powerful rural interest groups are aligned with the VP process. In India, market-distorting policies have included price ceilings and marketing restrictions on sugar and molasses, price floors and taxes on cane, licenses for expansions and new plants, low-interest credit for capital and operating costs, and in some states subsidies for cane purchases. The net effect of these policies may be to favor OP over VP for old plants and vice versa for new plants.

In Kenya, the VP sugar industry has been the largest recipient of government investment funds in the industrial sector, mostly through joint ventures with foreign firms. As sugar price controls have eroded profitability, these firms have been taken over by the government. The government allows the plants to continue operating at a loss by not recouping depreciation costs and by providing subsidies. Some of the large plants manage tracts of cane land belonging to key government officials whereas small plants would not be able to do so.

Technology Choice By Parastatals

James (1986) examines the appropriateness of the technologies chosen by parastatal manufacturing enterprises in Kenya and Tanzania. Although the stated policies of the two countries are very different (nationalistic capitalism in Kenya and socialism in Tanzania), parastatal companies have adopted similar types of inappropriate technologies in both countries. For the most part, the scale, factor intensity, and product characteristics of the adopted technologies have followed the pattern of large industrial facilities in developed countries.

This choice of inappropriate technologies can be explained by institutional aspects. Parastatal managers receive bureaucratic rewards by starting up new projects, particularly large projects that are highly visible. The availability of finance is the key limiting factor in starting projects. Often, the easiest way of obtaining financing is to build new plants with the support of aid donors (including the multilateral development banks) or export credits. It is more difficult to obtain subsidized foreign financing for technical modifications of existing plants or undertaking managerial reforms. It is also more difficult to manage a large number of small-scale projects.

Parastatals often defer decisions on the choice of technologies to the aid donors and exporters of equipment. As a result, most of the technologies that are chosen are those currently being manufactured or used in developed countries. Thus, the characteristics of the products produced with these technologies are more suited to relatively affluent consumers in developed countries. Parastatals often try to justify these product characteristics by citing the need to export, but frequently they cannot compete in export markets.

Bilateral donors often tie aid to sources of equipment from their own countries. Similarly, the staff of multilateral banks and development assistance agencies are more familiar with modern technologies and frequently insist on technical consultants from developed countries. Donors face a "pipeline" problem of spending their resources expeditiously

and bureaucratic incentives in these organizations also promote new, large-scale projects.

Other parts of the government in less developed countries usually allow these investments in inappropriate technologies even when there are stated policies encouraging decentralized, small-scale or labor-intensive production processes. Parastatals have little accountability because government objectives are usually ambiguous since politicians resist quantifying tradeoffs among conflicting, multiple objectives. Moreover, the parastatals are often under pressure to maximize output quickly regardless of cost. Subsidies, trade protectionism, monopolistic markets, and price controls shield parastatals from the profitability concerns of private companies in a competitive economy. In some cases, powerful individuals in parastatals or the government profit from their special interests in the projects (legitimately or illegitimately). Large capital-intensive projects with foreign suppliers offer the largest potential for such gains in fungible currencies.

The potential for adopting more appropriate technologies would be greater if parastatals are forced to be more accountable for their profitability and more competitive with foreign producers, or if economic activities are divested from parastatals to local, private enterprises. Equipment suppliers and technical experts from other less developed countries may be more likely to promote appropriate technologies than those from developed countries. Greater consideration of the suitability of product characteristics for consumers in the country, more realistic targets for increases in output, and changes in macro-policies that distort market signals would also be needed.

In-plant Technical Change

Maxwell (1986) summarizes the findings of the Inter-American Development Bank/Economic Commission for Latin America research program. This program of nearly forty case studies examined indigenous technical change in process plants (e.g. chemicals, petrochemicals, rayon, steel, cement, and cigarette production plants), metal working plants, and capital goods enterprises in newly industrializing countries in Latin America. Most of these plants are large-scale, capital-intensive, urban, and oriented toward production for import substitution. Although these studies are not directly concerned with appropriate technologies, they are among the few studies that have looked into the subject of long-term, indigenous technical change.

Modern sector industrial plants in newly industrializing countries rarely have standard designs because of the cumulative effect of successive technical and managerial modifications. A large number of minor technical changes are

needed to get new plants fully operational. Most of these changes are defensive reactions to unexpected conditions within or outside the plant such as equipment breakdowns, bottlenecks in raw material supply, or labor problems. These modifications are usually made by the plant's own staff and indigenous consultants based on their specific knowledge of the plant's actual problems and opportunities. Later, major changes may be required for upgrading the plant to incorporate new technologies, diversify the product line, or respond to pressures from competitors or government interventions. Successful firms are the ones with access to the necessary expertise that allows them to be most adaptable in making these modifications, but this gradual learning process can take years. Some firms respond defensively or fail to respond while others are more proactive.

As a result of this continuous process of indigenous technical change, the long-run trajectories of technology within an industry differ a great deal between countries and among plants within the same country. In the particular industries studied, the appropriateness of indigenous technical changes varied. Many of the long-run changes increased the scale and capital intensiveness of production, raising the capital/labor ratio while decreasing the capital/output ratio and the labor/output ratio. However, the changes allowed greater use of local raw materials, increased the efficiency of raw material use, and improved product quality through more accurate selection and control of raw materials. In some cases, too rapid expansion of the plant caused serious problems in design, construction, or operation. Thus, the rate or magnitude as well as the type of technological change can be inappropriate. It should be noted that these modern industries existed in a dynamic environment of technical change originating from the developed countries and that the studied firms are not a random sample from those particular industries in the newly industrializing countries.

Standardization of Machine Tools

Standardization in the machine tools industry offers many advantages. It can (1) reduce the burden of design work on firms, (2) shorten delivery times, (3) improve quality specifications and facilitate inspections; (4) encourage mass production and subcontracting through interchangeability, (5) allow carrying of smaller inventories of parts, (6) make maintenance and repairs easier, and (7) increase the ability to compare prices of machine tools on the market.

The negative effects of machine tool standardization include the (1) costs of establishing and enforcing the standards, (2) costs of requiring firms to change product specifications, (3) possibility of forcing some small and medium-scale enterprises out of the market in the short-run,

and (4) their static nature if not revised frequently enough.

Kiyokawa and Ishikawa (1986) compare the growth of the machine tools industry in Japan and China, and relate differences to divergent rates of the adoption and effectiveness of implementing standards. Although the early-industrializing countries mainly relied on standards set from below by companies and groups, the late-industrializing countries such as Japan and China had to catch up by setting standards from above by the national governments.

During the period of 1931-45 in Japan, key industries including machine tools were underdeveloped and uncompetitive. Machine tool factories were unspecialized, producing a large variety of low-quality machine tools to order in small volume runs. The lower price of domestically produced machine tools did not sufficiently compensate for their inferior accuracy, efficiency, and durability compared to imports. World War II stimulated the development of machine tool standards in Japan by forcing the country to become independent from embargoed foreign suppliers and by increasing the demand for large, military equipment. Because of a shortage of skilled labor during the war, single-purpose machine tools which required less skill replaced universal machine tools. At first, upgrading of this industry largely took place through imitation of imported machine tools. Although the imitations of the tools were of low quality, this intermediate step helped to upgrade the technology in use and build skills within the firms.

Effective standards for machine tools, machine elements, materials, and electrical equipment made a substantial contribution to the growth of this industry in Japan during the post World War II period. They allowed Japanese firms to specialize in machine tools and parts and to increase technical ties with foreign companies. Enforcement of the standards was combined with subsidies and tax exemptions for first-quality machine tool firms, and distribution controls on iron and steel. As skill levels rose and companies were freed from duplicative design work, domestic R & D for significant machine tool innovations boomed. As a result, Japan is now one of the major producers of high-quality machine tools for the domestic and export markets. Due to the importance of machine tools as an intermediate good in the industrial sector, the effects of these changes on the whole economy were very large.

Prior to 1949, there was virtually no machine tool industry in China and various foreign standards were accepted in different regions of the country. After 1949, most of the machine tools produced in China were imitations of Soviet models of low-quality, universal machine tools. A large proportion of the output was defective due to a shortage of skilled labor and the lack of quality standards or systematic inspection.

Chinese industry between 1958 and 1983 faced a similar period of breaking free from inferior imitation of foreign technologies. The number of machine tools produced increased dramatically during the Great Leap Forward of 1958-1960, but this did not bring about a real development of the industry. These tools were produced in small workshops in villages and towns that lacked technical assistance and suitable quality materials. By 1962, some modern factories built with Soviet bloc assistance began trial production of large, precision machine tools. Full-scale production was precluded by the lack of enforcement of industrial standards even though some provisional standards had been set in 1960.

After 1962, efforts at setting standards increased, but these were still modeled after those that were appropriate for Soviet conditions and, thus, were not taken seriously by Chinese plant engineers. This work virtually stopped during the Cultural Revolution of 1966-76 because the idea of standards became politically unacceptable. As a result, the quality of machine tools was inadequate. After the Cultural Revolution, the revived standards were largely obsolete. It was not until 1978 that Chinese standards began to catch up with technology, but their implementation was still hindered by the "self-contained factory" system and the weak incentives for communal enterprises. Shortly thereafter, quality control was heavily promoted and market incentives liberalized and now the machine tools industry in China shows considerable promise.

The question of the appropriateness of this technology cannot be separated from the choice of industries for the whole economy. The changes in the machine tools industry increased the capital intensity and scale of production. Due to the special importance of this industry, that pattern of development may have been appropriate in this case as unemployment problems were solved by labor-intensive industries in other sectors of the economy. Product standards for intermediate goods are more likely to be appropriate than standards for consumer goods which often reflect the preferences and incomes of affluent residents of developed countries.

Overview of Macro-policies

Stewart (1986b) concludes this set of papers by hypothesizing that the inappropriateness of macro-policies has impeded the development and dissemination of appropriate technologies more than the limited resources devoted to micro-interventions. With a proper accounting of policy-induced distortions, many large investments in modern, industrial technologies would not be optimal from an economic or a social standpoint. Yet, large-scale projects can preempt investments in more appropriate technologies. Thus, a better

balance is needed between donor support of appropriate technology projects and efforts to promote policy reforms.

To accomplish policy reforms, institutional changes may be necessary to reorient the objectives and decision making processes of government agencies, parastatals, development banks, and aid donors. It may be more difficult to change the actual objectives of these organizations than the stated ones because of the special interests of key actors within the organizations as well as external political pressures.

Some specific actions that could increase the use of appropriate technologies include (1) substituting sectoral aid for project aid, (2) supporting smaller projects and enterprises, (3) implementing projects through nongovernmental organizations, (4) eliminating tied aid, (5) obtaining technical assistance and equipment from other developing countries, (6) financing recurrent costs and local currency costs rather than just capital and foreign exchange costs, and (7) supporting more R & D for appropriate technologies. In addition, the resources available for private investment in appropriate technologies are strongly affected by pricing policies for inputs and outputs, interest rates and access to credit, trade protection, the size-composition of enterprises and the degree of competition, and product standards.

Policy Activities In Progress

ATI has begun several additional policy activities. It is supporting a project that will examine the conceptual and empirical literature on technology transfer to produce guidelines on how to encourage the replication of the innovative elements of demonstration projects. That study will examine the factors affecting spontaneous replication, the potential for interventions to speed up the replication process, and the policy constraints to replication in selected countries. ATI is supporting another study on how to go about down-scaling modern technologies. ATI is also collaborating with Private Agencies Collaborating Together (PACT, Inc.) on a conference to be held in West Africa in 1986 on small-scale technologies for extracting edible oil from seeds and nuts.

In 1985, AID began support of a five-year project on "Assistance to Resource Institutions for Enterprise Support" (ARIES). This project is being carried out by Robert R. Nathan Associates, the Harvard Institute for International Development, Control Data Corporation, and ATI. The purpose of the Aries project is to strengthen organizations working with very small businesses in less developed countries. The project activities will include research and preparation of

case studies, development of training materials for local development assistance organizations and their clients, and provision of technical assistance to programs supported by AID missions.

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