ISSN-0734-9168

IMPACT ASSESSMENT BULLETIN

198

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International Association for Impact Assessment

THE IDENTIFICATION OF APPROPRIATE TECHNOLOGIES FOR RURAL DEVELOPMENT

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THE DEFINITION OF APPROPRIATE TECHNOLOGY[1]

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 à 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 1987a).

Under the technology specifications approach, the expected outcomes of a technology are compared to a list of characteristics generally associated with "appropriateness." These characteristics are defined in terms of the expected socio-economic impacts on the poor in rural and/or urban areas, and 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 "signposts for action." (Ibid.)

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[1]The contents of this article do not necessarily reflect the views of Appropriate Technology International

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. 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.

Appropriate technology projects can be most cost-effective and will have the fewest unintended, negative impacts when low-income people 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. Such opportunities are neglected by commercial sources of capital because they are relatively risky, small scale, and non-urban.

The following classification of technologies is useful in testing assumptions about technology transfer:

- **Traditional technologies** are those that have been used in production or consumption for at least 25 years. In some cases, they have been introduced from another less developed country (LDC) rather than being of indigenous origin. Traditional technologies usually rely on human or animal power, or renewable energy sources.
- **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 scale.
- **Off-the-shelf modern technologies** have been in use for a relatively short time, generally less than 25 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 (James 1984).

Each of these types may be appropriate for particular situations in LDCs, but upgrading traditional technologies is often the most cost-effective way of reaching the rural and peri-urban poor. Upgraded traditional technologies often retain the accumulated environmental knowledge of local people and are more compatible with cultural values, local skills for operation as well as repair, and resources than are down-scaled modern technologies (Ibid.). 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.

In down-scaling modern technologies, many of the economies of scale that make the technology efficient may be lost (Ibid.). 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 LDCs 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).

Since an appropriate technology must be matched to the needs and resources of a particular application, a case studies approach is important in documenting the impacts of technology choice and the dissemination of strategy. Although this information can provide useful lessons on what has or has not worked, it must be evaluated in light of the specific features of the case. Nevertheless, many appropriate technologies have a high replication potential in large areas of the Third World. Multiple factors need to be considered in the choice of technologies by private enterprises or designers of a development project (Table 1). However, it is sometimes possible to identify the key factors in the decision and the case studies discussed below are categorized in this way.

Table 1: **Key Factors in the Appropriateness of a Technology**

1. Scale of equipment and processes
2. Cost savings
   (a) Capital
   (b) Operating, maintenance and replacement
   (c) Foreign exchange
3. Generation of profits
   (a) Increased production
   (b) Higher prices for products
   (c) Value added locally through processing
4. Socioeconomic impacts and distribution of benefits
   (a) Directly increases employment for rural and low-income people
      i. Creation of new jobs
      ii. Higher wages due to better labor productivity or skills
      iii. Reduced labor displacement
   (b) Increases net incomes of other enterprises
      i. Greater demand for locally produced raw materials
      ii. Higher profits in subsequent use or processing of the products
      iii. Reduced share for middlemen
   (c) Provides benefits to rural or low-income consumers
      i. Reduced prices
      ii. Improved quality of products
      iii. Greater availability of products
5. Environmental Impacts
   (a) Natural resources consumption
   (b) Amenities
   (c) Health

SCALE OF EQUIPMENT AND PROCESSES

Generally, a range of technologies exists for different scales of production. Small scale is not an end in itself, but is often associated with other characteristics of appropriateness. A case in point is the medium-scale "open pan" (OP) process for sugar manufacturing, which can be a viable alternative to the large-scale, "vacuum pan" (VP) process (Kaplinsky 1987). The typical capacity of a VP sugar mill is 1,250 tonnes of cane per day (tcd) in India and 7,000 tcd in Kenya, compared to 100-200 tcd for an OP plant.

Until 1982, the OP process had a serious disadvantage which made it uncompetitive — a low crystal sugar recovery rate. As a result of R & D work in India, the recovery rate has been improved and the labor and fuel requirements have been reduced. For a new plant, the production costs per unit of output for a 200 tcd OP plant are 16% lower than those of the typical VP mill in India and 34% lower than those of a typical VP in Kenya. 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 serve smaller, cane producers. 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 (ibid).

The choice of an incorrect scale can make a technology inappropriate for a particular setting. 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 appropriate in a project of the Malawi Fisheries Department. Ferrocement is a mortar of cement, sand, and water that is densely reinforced throughout with steel mesh wire and formed into a thin shell. The main justification for this material in boat building is the scarcity of suitable timber in some countries and the potential longer life of a ferrocement boat due to its resistance to fire, termites, and borers. Construction of a ferrocement boat is labor-intensive, but demands less skilled labor than for a wooden boat. Other alternatives such as steel or fiberglass are much more expensive and require more imported material.

An innovative construction method allowed ferrocement boats as small as 5.6 m in length to have a sufficiently low weight in proportion to the length. Nevertheless, this boat size is still too big for fishermen on the

northern shore of Lake Malawi. About 99% of the fishermen there are now using simple dugout canoes with oars and 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 a ferrocement boat and a commercial analysis showed that it could be profitable, successful operation would require 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. Most fishing entrepreneurs preferred to buy another canoe or more gear instead of a larger boat. Moreover, there is also little tradition of sailing in Malawi, although it exists in the Mozambique-controlled portions of the Lake (Hyman 1987a, forthcoming).

COST SAVINGS

Capital Costs: Many technologies are appropriate because they require less capital than alternatives of comparable productivity. Edible oil extraction is a basic industry in rural areas and diesel-powered expellers are expensive to purchase and operate. Consequently, ATI provided technical assistance and financing to a medium-scale, private workshop in Tanzania (the Themi Farm Implements and Engineering Co.) for production of two types of manually operated oil presses for sunflower seeds to fill different market segments. The first is a medium-scale press (T.S. 150,000 in 1986) designed at the University of Dar es Salaam. When this press is used with a centrifugal impact dehuller and a seed crusher, 60 liters of oil can be produced per day from 200 kg of sunflower seeds. 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 (T.S. 15,000 in 1986), 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 from 200 kg of sunflower seed, but at a slower rate of about 24 liters per day. This press is being sold to village groups with financing through a revolving loan fund.

Operating, Maintenance, and Replacement Costs: Other technologies can reduce operating costs in exchange for higher capital costs, often because they rely on free sources of renewable energy. Approximately 60,000 water pumping windmills are in use in Argentina, mostly to provide water for high-valued beef livestock. About 1,500-2,000 windmills are now being produced in Argentina each year by over 20 manufacturers. The design modeled after the U.S. multiblade fan type does not have as efficient a mass-to-output ratio as some of the newer U.S. models, but it is a proven design which requires less precision in manufacture and is less expensive and easier to maintain (Fricke 1984).

Some technologies offer savings in both capital and operating costs over conventional alternatives and can operate where traditional alternatives are ineffective or relatively unproductive. 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 are only suitable for surface water or very shallow wells of less than 1.2 meters. 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 $21.00), but this advantage evaporates if only 9 or fewer acres are served. Since most farmers in Bangladesh only have 0.5 acres of dry season rice to irrigate, they cannot afford the high capital cost of the mechanized pumps, and irrigation cooperatives in Bangladesh often tend to break down (Biggs and Griffith 1987).

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 (Ibid.) If this labor is priced at the market wage for casual agricultural workers, the operating costs per acre are also higher for handpumps than for mechanized pumps. Yet, most of this labor is provided within the household and 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.

Foreign Exchange Costs: Imported raw materials or spare parts for machinery can be especially costly for small industries and farmers, when

they are available. In some countries, overvalued exchange rates for domestic currency lead to import controls or foreign currency rationing. Certain national planning agencies place a premium (shadow price) on the social costs of using foreign exchange above and beyond the actual expenditure.

An example of the short-term importance of an imported raw material and the difficulty of relying on it in the long-run is the case of swine feeds in the Dominican Republic. Following the slaughter of the entire national herd as a result of African Swine Fever, farmers who obtained new pigs through government programs were required to buy balanced imported feeds. During the initial period, farmers earned high prices for the pigs they raised or bred due to the scarcity of the animals. As pig repopulation has progressed, the prices received by farmers have fallen. At the same time, the real cost of imported soy and maize-based feeds increased greatly with devaluations of the local currency. This squeeze from both costs and product prices has forced farmers to look for alternative feeds. Although traditional feeds such as cassava leaves and surplus tubers, sweet potato leaves and stems, and palm nuts are low cost, they do not provide a balanced diet by themselves and can result in slow growth.

ATI and CIMPA, an NGO involved in livestock development, are encouraging the use of molasses, ramie (a green chop), and a commercial protein source with added vitamins and minerals to supplement the traditional feeds. Molasses, a byproduct of the domestic sugar industry, is an inexpensive source of energy. Molasses makes wild plant forage palatable to pigs and enables a larger proportion of the diet to be green material. For a breeding pig, forage can substitute for 45% of the calories provided by imported commercial feeds and molasses can provide another 15%. The molasses and protein supplements are sold through a network of existing, local cooperative stores. The ramie can be grown by the pig farmers on marginal land from cuttings provided by the project.

THE GENERATION OF PROFITS

Appropriate technologies can increase revenues by increasing the quantity or value of production on farms and in rural industries. This can take place through the expansion or intensification of existing activities or the establishment of new ones. For example, the Themi Farm Implements and Engineering Co. mentioned earlier was started in 1982 with loans and technical assistance from AID. Themi began by concentrating on two

products: wooden oxcarts in complete or kit form and metal toolbar-plow sets. Themi also produced plow attachments such as cultivators, harrows, ridgers, and planters. Before beginning production, Themi carried out a market survey for the region. As the market for oxcarts became saturated later, Themi changed its production mix. Due to efficiency gains in production, Themi has been able to reduce its prices.

This equipment is appropriate in Tanzania because of the shortage of agricultural labor during the limited planting and harvesting periods. Small farms there 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 project took place at a time when 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 (Fricke 1984).

Another way of achieving an effective increase in production is to reduce waste losses. 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 storing maize, sorghum, and beans in Central America since the early 1900s and are made by individual artisans. The bins keep grain clean, dry, and cool to reduce spoilage. They reduce losses from birds, rodents, insects, and micro-organisms. 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. Farmers in Costa Rica have less of an incentive to store grain because a national grain storage agency maintains stable prices for grains (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 is portable and has a storage capacity of 1 tonne; it costs $35 in Central America. A bin should last 15 years under typical conditions and could last 25-40 years if well built and maintained. Proper grain management techniques such as sorting, drying, cleaning and fumigation are needed to take full advantage of the equipment. If properly managed, the [illegible]

years, but most farmers only store it for 9-12 months.

One reason for the unequal distribution of income between rural and urban areas is that common marketing systems for agricultural, silvicultural, or mineral products do not allow small producers to participate directly in the transport, resale, and processing of their products. In many LDCs, government policy has favored urban interests over rural ones by keeping food prices low for consumers or establishing parastatals as sole buyers or processors of export commodities. Policies have also favored the location of processing industries in urban enclaves. Where income distribution has been a policy objective, governments frequently have emphasized land reform or large-scale investments in irrigation or transport and have paid little attention to commercial relationships in marketing and purchasing rural commodities (Shoemaker 1981).

Yet, some rural industries have inherent efficiency advantages over urban enterprises in processing primary products. That is the case in the processing of the seeds of the achiote tree (Bixa Orellana) into annatto (a reddish-orange food coloring used in cheddar cheese, cereals, and snack foods.) Peru is the largest source of annatto, with more than 50% of world production. Before the early 1980s, Peru mainly exported raw seeds for processing in developed countries. Since then, a domestic industry for the initial stages of processing developed in Lima as a result of the higher transport costs for shipping unprocessed seeds (the colorant only comprises 8% of the weight of the seeds) and higher labor costs in importing countries. Although domestic processing increased the value added in the country, it largely bypassed the rural producers. Achiote was a low-valued crop for farmers because most of the profits were obtained in processing and by several layers of middlemen involved in the transport and resale of the seeds. ATI supported the establishment of the first processing plant owned and operated by a cooperative of rural producers. The location of the plant closer to the source of the seeds reduces transport costs, and losses in transport and storage from exposure to heat, moisture, and friction in handling. The prices paid the farmers are also expected to increase as competition reduces the oligopoly power of middlemen (Hyman submitted).

SOCIOECONOMIC IMPACTS

Provision of Employment: Some of the pioneers of appropriate technology urged more support of traditional technologies such as the simple

spinning wheels Gandhi spoke about in India. In this view, labor intensity and being small-scale was inherently good (Schumacher 1973). Although partly a reaction to the money spent on large-scale, modern technologies that did not trickle down to the rural masses, this view was also motivated by the need to provide income to large numbers of unskilled workers through simple, productive employment opportunities. Taken to the extremes, it led to the inefficiencies motivated by the desire to maintain employment in local industries. For example, to support a small, local pottery, a government nursery in Karnataka, India used inconvenient, heavy clay pots in transporting tree seedlings to planting sites instead of cheaper plastic bags which were readily available.

Sometimes, labor-intensive techniques can also be the least costly. For example, in the mid-1970s, Kenya began a program of constructing rural access roads with the use of simple hand tools such as hoes, shovels, picks, machetes, and rakes. The total construction costs per kilometer of road were $7,200 by the labor-intensive method, versus $8,300 by the conventional method. By minimizing the use of expensive equipment, employment was created for an additional 200-300 unskilled laborers. This program was successful because of technical assistance and close supervision of workers through a decentralized management system. It gathered much political support because workers were hired from the vicinity of the roads (Fricke 1984).

Labor-intensive production does not always revolve around a "hard technology." The key feature may be the way in which production or distribution is organized. The Lijjat Pappad cooperative is a significant example because it provided remunerative labor for a particularly neglected group, women. The cooperative began in 1959 with 7 members and grew to over 6,000 members producing gross sales of $3.4 million by 1980. The coop produces an unleavened, Indian flat bread made of lentils and flour through a combination of light industrial and home processing. The ingredients are bought in bulk and ground at the coop's mill in Bombay. From there, they are transported to 21 local centers to be combined using hand mixers, formed into large balls of dough, and weighed. The dough balls are distributed daily to coop members who roll them into flat, round sheets and dry them in the sun. The next morning, the finished pappads are brought to the coop centers for quality control inspection, packaging, and distribution to private marketing agents paid on commission for domestic and export sales. The production and marketing system minimizes working capital requirements and avoids regular

government marketing outlets for coops (Ibid.)

New employment can be generated by the manufacturing of additional products by using raw materials more efficiently. This is the approach of a joint venture between ATI and the Filipinas Foundation for coconut oil extraction. The conventional technology uses an expeller to remove oil from copra. An alternative wet process extracts the milk from fresh coconuts, separates the skim and cream portions of the milk and boils the cream to break the oil-water emulsion. The wet process allows production of other products such as laundry soap and food items such as nata de coco, coconut skim milk beverages and a flour substitute from the byproduct cake without a direct tradeoff in oil production (Hyman 1987c).

Large-scale import substitution, particularly for heavy industry has been discredited as a development strategy because of the net loss in jobs from diverting production out of areas of comparative advantage. However, import substitution can create new jobs in a country where domestic production can match or surpass the efficiency of production in the exporting country. For example, a mushroom venture in the Philippines supported by ATI achieves efficient import substitution by combining centralized biotechnology techniques with simple, low-skilled household production in a two-stage operation. This method takes 108 days per batch compared to 165 days for the traditional method of growing oyster mushrooms on logs. The bagged spawn will be sold to households near the central facility under a contract growing scheme. Tending the mushrooms is easy; maintenance of the proper temperature and humidity, control of pests, and harvesting can be a part-time task for women and children. The venture establishes a guaranteed market for the harvest at a fair price. It resells the mushrooms to supermarkets and restaurants in Manila that previously obtained mushrooms imported from Hong Kong or China.

Some skeptics have criticized the idea that the most labor-intensive technology is necessarily the most appropriate and have suggested that such technologies are backward or inefficient (Eckaus 1986). Actually, an appropriate technology may displace some labor or animal draft power of low productivity. However, there will usually be less displacement than would occur with a more capital-intensive technology. In the short run, an upgraded traditional technology may reduce employment per unit of output. However, by increasing the quantity of output to meet an expanding market, the total employment in the industry may increase in the long run. Where the traditional industry is declining due to foreign competition or substitution of other domestic products, productivity increases may be necessary just to preserve existing jobs.

An example of this is in Costa Rica where ATI is working to upgrade the traditional process of making lime to increase the quantity and quality of production, while using less labor for loading and unloading the charge of lime. The changes reduce variable costs as well as occupational health and safety problems from exposure to high temperatures and lime dust. The improved kiln also reduces fuelwood consumption per unit of output by 15-20%. Modification of the kiln and the associated processes of hydrating, milling, and packaging the lime will boost the demand because the product quality becomes suitable for housing and road sub-base construction as a substitute for cement. This lime would also meet the specifications for the sugar milling and leather tanning industries which previously had to import lime because of the poor quality of the domestic product.

There can be a tradeoff in the short-term between the number of jobs and wage rates in that occupation. As the skills of the workers or the amount of capital per worker increase, wages can be raised above the subsistence levels typically received by unskilled labor. In the above case, the wages of lime workers can be expected to rise.

Often, laborious farm or household work is performed by women who do not receive direct remuneration for it. Simple small-scale technologies can reduce the drudgery and effort required for these chores so that the time could be devoted to more productive uses. In West Africa, rural women commonly spend two hours a day in the strenuous job of dehulling and milling grain. Between 7 and 13 kg of millet can be dehulled per hour with a mortar and pestle, but the recovery rate is low, approximately 70%. The pounded millet must be used the same day because it spoils rapidly due to its high moisture content. As a result, urban households and some rural households have been switching to imported wheat or rice products that require little preparation time. Between 5 and 10% of the millet consumed in Mali undergoes wet processing in a large-scale Engleberg dehuller for a service fee. The Engleberg dehuller has high capital costs and fuel costs, and also results in a short storage life for the grain. An alternative mini-dehuller which uses a dry process has been designed by the International Development Research Center (IDRC) and

is being disseminated in Mali and the Cameroon by ATI.

The degree of labor displacement resulting from a technology can differ substantially across countries and even regions within a country. The traditional means of threshing and winnowing rice by hand, foot, or animal power are slow and waste grain. The International Rice Research Institute (IRRI) developed some threshing and winnowing machines that are less expensive than the large-scale equipment produced in developed countries. These threshers can handle wet grain and have a high separation efficiency. They can be easily manufactured by workshops in developing countries because they do not require any special materials and have no complex parts. The medium-scale IRRI thresher has a capacity of one tonne per hour. 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. By 1984, at least 79 small firms in the Philippines and 30 larger firms in Thailand had produced about 55,000 threshers (Duff 1987).

The impacts of the thresher on farm labor have differed in the two 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. Farmers who do not own an IRRI thresher can hire the services of one from larger farmers and nonfarming contractors. Over 70% of the purchasers did so without formal credit; 45% did not own land and bought the threshers to do contract work. 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. Thus, 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%. A small amount of employment is generated 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 landless poor who previously had the right to glean grain left after hand harvesting have been the major losers (Ibid.).

The social impacts of displacing hired labor can be serious because they fall on the unskilled or the landless poor. However, traditional systems of distributing shares of the rice crop have been 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 have lost their traditional rights. Most economists believe that some labor displacement should be accepted 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.

Backward and Forward Linkages: Linkages or secondary benefits are changes in net incomes or employment that are indirect outcomes of an economic activity. Backward linkages pertain to industries supplying inputs for the activity, while forward linkages derive from industries that process or sell the outputs of the activity. One example of a backward linkage would be intensification of sunflower seed production following the establishment of an oil extraction enterprise in the vicinity. The use of the oil in the tortilla industry would be a forward linkage.

Linkages are excluded from an economic analysis of the activity from the national perspective to avoid double counting with the value of final goods and services, and because the profits of one firm are often at the expense of another firm in the economy. Linkages can be relevant in looking at impacts on the distribution of income within a local area or region of the country. In general, it is only valid to count such impacts where there is excess capacity in existing production units or when labor or other resources that would otherwise have been unemployed are tapped. Otherwise, an expansion of output in one use has an opportunity cost in terms of withdrawing resources from other uses.

The types and extent of linkages to the rural economy vary with the development strategy chosen. Many aspects of the economies of Taiwan and the Philippines were similar in 1960, but since then per capita income rose at 6.9% per year in Taiwan and only 2.8% per year in the

Philippines. Both countries experienced comparable growth in agricultural production. However, agricultural labor productivity, industrial employment, and nonagricultural rural employment rose at a faster rate in Taiwan. Consumption linkages (including public services) 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. In addition, more rural industries that were not linked to agriculture developed in Taiwan (Ranis and Stewart 1987).

Consumer Benefits: Production by the masses is not the only way in which low-income people can benefit from appropriate technologies. Production for the masses of goods that meet basic needs can be equally important. Consumers can benefit from lower prices and the improved availability or quality of products. For example, use of a simple, hand-operated brick press and an improved kiln can produce a larger quantity of bricks that are also cheaper and more durable than those made through slop molding and firing in a field clamp. However, the upgraded technology does not employ as much unskilled labor (Kaplinsky 1986).

A lower quality product that is less expensive can also be appropriate for low-income consumers, especially where the product specifications reflect the tastes and preferences of middle-income consumers in developed countries. For instance the rural poor might choose to buy a lower grade laundry soap than the type purchased by urban or higher-income rural consumers. Yet, the cheaper products are not always manufactured for this market.

The total costs of a cheaper, less durable product can be less than those of a higher grade product even after considering additional maintenance and replacement costs. For example, fishermen might save money with a cheaper sail made from local drill cloth instead of imported material, even if the local cloth does not last as long. However, certain products with lower initial costs can end up costing consumers more in the long-run. Sometimes, the trade-off is appropriate because consumers cannot afford the higher initial costs, but many products are unsuccessful in the marketplace because they are not beneficial for consumers.

One such failure is the fiber-reinforced roofing sheets promoted by the Intermediate Technology Building Materials Workshop. This material consists of sisal or coconut husk fiber (coir) mixed into portland cement, water, and well-graded sand. The mixture is molded over a corrugated former and cured for several weeks. Up to 50% of the fiber cement sheets produced in Colombia had visible cracks within 1 year because workers found it difficult to produce a mix with the correct proportions by hand, and to follow adequate procedures for casting and curing. Attempts to repair the cracks proved unsuccessful. With careful production and installation, experience in Sri Lanka shows that the cracking rate for smaller and thicker sheets can be reduced to 10%. 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.

Moreover, fiber-reinforced cement sheets become brittle under the weather conditions of the humid tropics due to decomposition of the fibers and bending of the sheets from their own weight. The fiber-reinforced cement sheets only last 2 to 4 years, compared to 12 or more years for galvanized iron. The higher material and labor costs for replacement of cement sheets outweigh the initial cost savings of 30-50% over galvanized iron (Lola 1985).

Certain products allow consumers to save money on fuel or water. 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. Since charcoal is a marketed fuel, users have a financial incentive to conserve it, unlike wood which is often collected for free. By mid-1986, 150,000 of these stoves had been purchased by consumers (Hyman 1987b). The concept of the stove combines Thai ceramic-lined stoves with the traditional Kenyan all-metal stove which came from India. The original design was substantially improved after field testing.

Dissemination began mainly in the Nairobi area with support from U.S. AID and the Ministry of Energy. This stove was produced and sold by small-scale artisans through regular marketing outlets on an unsubsidized basis. The improved stove costs about $4.00, while the traditional stove costs $2.50. The improved stove can last 2 years, twice as long as the traditional one. Accounting for the initial costs, periodic replacement of the liner for the improved stove and the grate of the traditional stove, replacement of the metal cladding, and the charcoal savings, an average

Nairobi household would save $31 over a two-year period by replacing a traditional stove with an improved stove (Hyman 1986).

Consumption benefits can also accrue to other producers when the product is an intermediate good. Consider an enterprise producing rhizobium inoculant for farmers of leguminous crops. Rhizobia are nitrogen-fixing bacteria that have a symbiotic relationship with the root nodules of such plants 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, rhizobium innoculant can reduce the need for nitrogen fertilizer while increasing the productivity of legumes by 20-50%. Chemical sources of nitrogen are often imported into developing countries, but are expensive and constitute a large share of the cash costs of small-scale farmers.

ENVIRONMENTAL IMPACTS

Many of the technologies discussed above have favorable impacts on environmental quality or natural resource consumption or less negative impacts than those associated with other alternatives. For example, an improved lime kiln decreases fuelwood use and more efficient charcoal stoves reduce charcoal consumption. Unlike commercial fertilizers, rhizobium inoculant does not contaminate rivers with nonpoint source runoff. Hand-operated pumps, oil extraction equipment, and grain mills do not release air pollutants from combustion of diesel oil. Animal-drawn agricultural machinery is less likely to compact the soils. Similarly, small-scale wells are less likely to drawn down the water tables than large wells and are not associated with increases in disease rates for malaria or schistosomiasis as are large dams. In comparing the environmental impacts of a small-scale technology and a large-scale one, the assessment has to be based on the same total level of production. A variety of techniques are available for assessing environmental impacts (Hyman, Stiftel, Moreau, and Nichols 1987).

CONCLUSIONS

The transfer of new technologies across countries or within a country often fails because the equipment or processes are not compatible with the economic, social, or natural environment. Frequently, such failures can be predicted if a thorough ex ante assessment of the likely impacts is done. Field testing of the technology before widespread replication can lead to important design modifications. The dissemination strategy can be as important as the appropriateness of the technology itself and government policies can also be a barrier to adoption of the most appropriate technologies (Hyman, forthcoming b; Stewart 1987b). Although external assistance in the development or adaptation of the technologies and in early promotional efforts is often necessary, the technologies with the largest replication potential can spread on their own if market incentives are satisfactory. Ex post analysis of impacts and documentation of the lessons learned from successful and unsuccessful cases can provide critical information for decisions about replication of the technology by private firms and farmers, government agencies, bilateral and multilateral aid agencies, and commercial sources of financing.

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