# 13 Technology Transfer for Development*

## INTRODUCTION

In some respects developing countries today have fantastic opportunities that were not open to the now-developed countries: there is a vast and growing array of technological knowledge, to which developing countries have potential access, that, with proper use, may transform them from a preindustrial state to a high-income, fast-growing sophisticated economy, in just a few decades. Yet this opportunity is also a threat. The highly advanced state of knowledge possessed by a few economies can lead to domination over less developed countries, with a high price levied for the technology they acquire, their main industries owned and controlled elsewhere, the characteristics of the technology transferred leading to imbalanced forms of development and environmental degradation, and attempts to avoid this situation by developing their own technology thwarted by competition from the highly efficient technology of the more advanced countries.

A few countries – for example S. Korea – have avoided most of the downside and succeeded in incorporating the technology transferred into their economic system, effectively adapting it to their own conditions, with a rapid and fairly balanced pattern of development resulting. But elsewhere experience has been less good: the technology transfer (TT) has created a dualistic society; productivity of the technology transferred has fallen much below what it was in the initiating country; growth has been slow; the technologies have been viable only under stringent protection; local technological efforts have been vapid; and the majority of the population has been left out of the growth process, experiencing only the negative and not the positive effects of TT. Sub-Saharan African countries present the most obvious example (see Lall, 1987b). But there are also examples in parts of Asia and Latin America, and many countries have experienced some negative effects of TT along with some positive effects. Even the most positive case – S. Korea – has experienced social,

* From Evenson and Ranis (eds.), 1990.

cultural and environmental dislocations as a result of the rapid transfer of technology.

The critical issues to be considered in this essay arise from these contrasting experiences. The question is what policies will help governments maximise the benefits and minimise the costs from TT. What form of TT should be encouraged? How much should be transferred, in which industries, at what price? What should government policy be towards R and D and other technological infrastructure? How do general economic policies influence the benefits and costs from TT? These are very difficult questions, and a short discussion cannot provide the answers. Experience also suggests that there may not be a single answer (i.e., alternative patterns of development are possible, depending on initial conditions and country objectives), while the answers change as development proceeds and countries' technological competence and negotiating ability improves.

## Objectives

It is necessary to begin this discussion by defining the objectives governments may have in their policy towards TT. We assume that a prime objective is economic growth that is equitable, in which most of the population participate, and that protection of the environment is also desired. Increased domestic technological capability is an important aim, both in itself and as necessary to achieve sustained and balanced growth. Economic growth that is totally reliant on foreign resources of technology and management and skilled personnel on a continuing basis would not be acceptable to most countries; moreover, it would not be efficient, as local technological capability is essential for attaining efficient levels of productivity and increasing productivity over time. The weight given to different objectives may alter the relevant strategy. While growth maximisation is a commonly agreed objective, whether or how much most governments are concerned about equity or the environment is less clear.

## The Market and TT

Recently market philosophy has come to dominate both much development writing and the major financial institutions. It has been suggested that the market is preferable to government intervention in most economic decisions.[1] Whatever the rights and wrongs of the general case for exclusive reliance on the market, the argument is clearly inapplicable with respect to decisions about technology. This is because technology shares many of the characteristics of a public good. While it is expensive to develop, once developed it costs relatively little to communicate.[2] This means that if allocation of technology-creating activity were left to a perfect market, very little technology would be developed (although, once developed, it would be almost freely available). This is clearly not a 'first-best' solution, since the total social benefits of technological developments would greatly exceed social costs. Two approaches have been developed to circumvent this problem in the developed countries: one is to provide public funds for R and D, usually requiring institutions so funded to provide the results to anyone who wants them free of charge. The other is to permit the private sector to keep secret or sell the results of their research, by allowing short-term monopoly practices and providing a legal system of protection in the form of patents. For the most part, the first solution has been adopted for basic research and also for much applied research for agriculture, while the second solution has applied to most industrial technologies.[3]

The system means developing countries can get free access to much basic research[4] and also to a good deal of agricultural research. But for industrial technology they must buy the knowledge from the companies who have developed it. The price they have to pay is dependent on the nature of the legal system protecting technology in the originating countries, the monopoly or oligopoly position of the technology sellers, and the bargaining position of the technology buyers.

While this system may be justified pragmatically by reference to the fact that it has been effective in producing considerable technological advances, it cannot be claimed that it necessarily produces the 'right' amount of research and development, with the 'right' characteristics, or at the 'right' price, from a theoretical point of view. This is even true for the developed countries – in whose environment and interests the system has evolved. The developing countries have been mainly peripheral to the system – both with respect to its institutional features and to the resultant technologies. Being more remote to the evolution and purpose of the system, there is more reason to suppose that a laissez-faire approach will not get the best results, and that an active strategy is necessary.

The developing countries are thus faced with an intrinsically imperfect market as far as TT is concerned, and with the need to develop their own system of government interventions to promote and protect technology-creating activities if they are to develop their own technology. They have to decide how far to intervene, and where, in the light of their own objectives.

Further to complicate the decision-making process, an essential characteristic of most efforts to develop or buy technology is uncertainty. When technology is being developed there is uncertainty with respect to what results the research will produce, as well as all the other uncertainties associated with any economic activity (e.g., about prices and markets). When buying technology, the uncertainty is caused by the fact that the buyers do not know what they are getting – if they did they would not need to buy it (Arrow, 1962). Against this background of basic uncertainty, the usual technique of decision-making, cost–benefit analysis, is inapplicable because too little is known about costs or benefits. Consequently, with neither the market nor cost–benefit analysis as a guide, countries are unavoidably making decisions on an inadequate basis. The best guide to decisions is to look and see what has happened elsewhere, but even here there are no infallible guides because it is normally not possible to discern which conditions were essential to success or failure, and which were just coincidental with them.

This essay aims briefly to review some of this experience to provide some policy guidance in this area. The next section discusses some basic facts about technological development and TT. The third section provides a quick overview of how the 'new' technologies bear on the issues being considered here. Policies towards TT in the light of the earlier discussion are then considered, and conclusions are presented.

## SOME BASIC CHARACTERISTICS OF TECHNOLOGY TRANSFER

A high proportion of world R and D takes place in developed countries, and much of that in large companies, often multinationals MNCs[5]. A 1978 survey of world R and D showed that only 2.9 per cent of expenditure (although a significantly higher proportion of scientists and technologists) was located in developing countries (Annerstadt, 1979). In 1975, 94 per cent of world patent rights were owned by entities located in developed countries, and of the 6 per cent registered in developing countries, 85 per cent were owned by

MNCs. Only 1 per cent of world patents were owned by LDC firms (UNCTAD, 1976).

In the early 1970s, the advanced countries had a near-monopoly on the world technology market, indicated, for example, by the fact that only 3 per cent of world production of engineering and electrical goods was located in developing countries, and just twelve developing countries accounted for over 90 per cent of this 3 per cent (United Nations, 1974). But this has been modified by some significant technology developments in a few developing countries – especially India, China, Brazil and S. Korea. Much of the R and D in developing countries has been concerned with adapting advanced country technology to LDC conditions, and – in contrast to advanced countries – a smaller proportion is spent primarily on product innovation, as compared with process innovation.[6] Technology-creation among some developing countries has widened the potential market for developing countries, but the advanced countries still largely dominate the nature and direction of technical change.

The value of TT – as indicated by royalties, fees and technical services – has grown greatly. For the five major industrialised countries it was $27 billion in 1973 and had grown to $222 billion by the mid-1980s. Receipts from developing countries represented around 20 per cent of total receipts for the USA and UK and a much higher proportion for Japan (nearly 60 per cent). By the mid-1980s, the approximate value of developing country payments to the major industrialised countries for technology was $6–7 billion (data from United Nations Centre on Transnational Corporations, 1987). This understates the true cost of TT since over-invoicing of imports and/or under-invoicing of exports is known to add substantially to the cost, while the price of imported capital goods includes some element of payment for TT (see the estimates of Vaitsos, 1974; Murray, 1981).

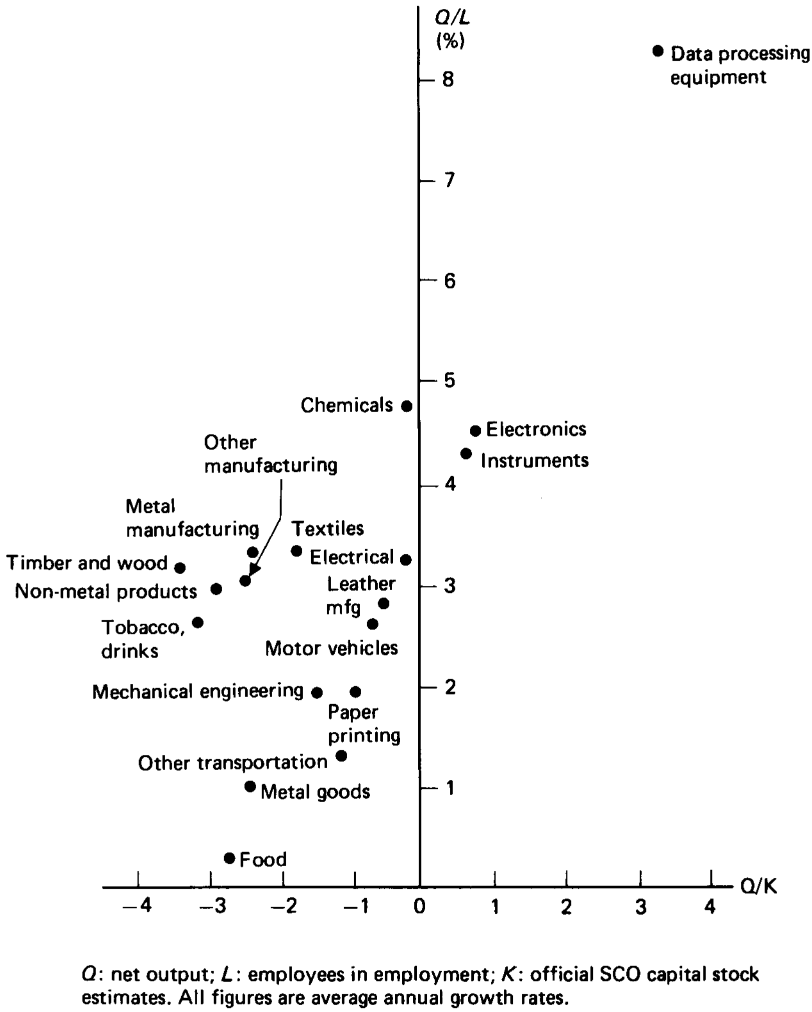
The choice of form of TT involves a varying degree of packaging of TT. At one end of the range is multinational investment, in which ownership and control remains with the technology seller. This was the dominant mode until the 1960s. However, new forms then emerged as countries pressed for more control; the development of international capital markets made it possible for finance and technology to be separated; and specialist engineering firms and smaller firms emerged, mainly in the developed countries, prepared to sell and service technologies on an arm's-length basis. Consequently, less packaged forms of TT developed, including joint ventures (shared ownership and control); licensing (ownership and management responsibilities lie with the host country, but the detailed conditions associated with the technology licence often introduce constraints on decision-making); franchising (sale of the use of a brand name and technical and managerial support); management contracts (supplying management and routine technical assistance); marketing and technical service contracts; turnkey contracts (supplying a 'finished' factory which is then handed over to the buyer); and sub-contracting (where the sub-contractor provides technical information to the sub-contractee).

Each of these arrangements involves specific payment for TT. In addition, TT takes place through trade – by importing machinery or by exporting when buyers often provide some TT. The range of options depends on the industry: the more monopolistic industries often prefer to keep control and will not agree to licensing (this has been the policy, for example, of IBM and Coca Cola, but competitive technologies have reduced this monopoly power). In general, more complex and more recent technologies are more difficult to acquire except through direct foreign investment (DFI). For example, a Japanese MNC refused to pass onto a Malaysian licensee the latest information on synthetic fibre, believing: 'it is not in the company's interest to pass all the technological information, which it had developed at great expense, to the host country' (Fong, 1987). A Korean firm was unable to secure technology for manufacturing polyester film (Lee, 1987).

Despite the emergence of 'new' forms, TT through direct foreign investment remains the dominant model. For the USA, four-fifths of receipts for technology are intra-firm; for West Germany over 90 per cent. The ratios are less for the UK and significantly less for Japan. The proportion of 'arm's-length' TT is higher for those countries that have aimed to avoid DFI and secure technology by other means. For example, India and S. Korea both made heavy use of licensing in the 1970s and for both DFI accounted for only a fraction of total TT.[7] Nonetheless there is heavy concentration as to source (a few industrialised countries), while those supplying technology under the new forms very largely consist of the 'same multinationals which dominate direct foreign investment . . . [who] also account for large proportions of production, trade and "new forms" of TT' (Lall, 1987c). According to Lall 'the supply side of technology still remains very oligopolistic in several industries'.

The origins of a technology strongly influence its characteristics, since most technologies are developed initially for production and consumption in the home market. Moreover, when there are major innovations (new 'technology paradigms'), a 'technological trajectory' follows, which clusters new innovations around the early developments, and locks further innovation into a particular direction (see Nelson and Winter, 1977). The continued domination of technology creation by the developed countries has thus meant that the developing countries are locked into the technological trajectories determined by the developed countries. The major characteristics of the technology have been determined by the environment in the developed countries with respect both to production conditions and consumption patterns. While growing technological efforts in developing countries have led to some adaptation, outside primary production these are all within broadly the same technological paradigm and trajectory. Consequently, technologies have tended to have characteristics corresponding to conditions in developed countries – being capital- and skill-intensive, and relatively large scale, producing products with characteristics suited to high-income markets – relative to the conditions and needs of developing countries. For the most part, these tendencies have increased over time, as real incomes have risen in the advanced countries, accompanied by rising capital per head and expanding education and skills, with the generation of demands for an ever-changing variety of increasingly sophisticated products. The technology emanating from the advanced countries has thus tended to become inappropriate over time, in relation to the needs of developing countries, especially low-income or slow-growing countries, both with respect to product characteristics and to techniques. (The one major exception to this trend comes from the microelectronics revolution – see below – which has reduced the minimum efficient size of production in some areas.)

Figure 13.1 shows changes in technology in the developed countries in recent years, indicating that in all industries capital–labour ratios and labour productivity have risen; in most industries this has been associated with rising capital–output ratios, but in the three industries most closely associated with the microelectronics revolution – electronics, instruments and data processing equipment – capital productivity as well as labour productivity has risen. Countries that adopt the more capital-intensive of the technologies produced by developed countries, without modifications, face a dualistic pattern of development with a small high-income sector absorbing almost all the countries' investible resources, its infrastructure and skills, generating demand among a small elite for the



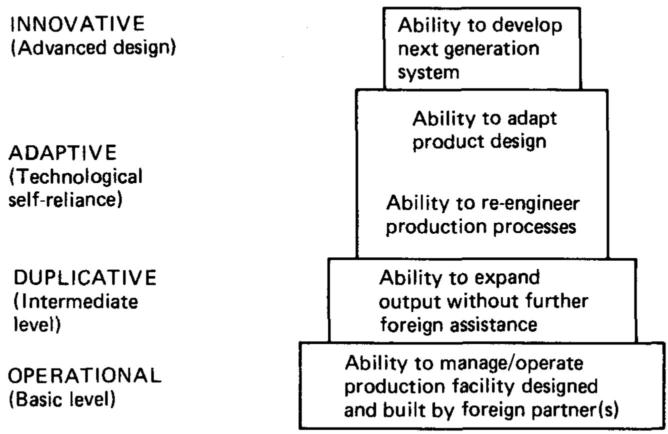

*Source*: Soete (1986)
*Figure 13.1* Post-war change in labour ($Q/L$) and capital productivity ($Q/K$) in the UK manufacturing sectors, 1948–84 by SIC sector

modern products produced in the sector, while the remainder of the economy, encompassing the majority of the population, remains deprived of investment resources, modern technology or appropriate products, in conditions of extreme poverty (see Stewart, 1977). Yet there remains considerable choice of technique: countries can choose to focus more on labour-intensive products, to direct more of their resources of credit and infrastructure to the rural areas and small-scale industry, to select older technologies and to modify imported technologies to suit local conditions, thereby avoiding the dualistic pattern associated with excessive and unselective use of advanced-country technology. Taiwan's development path presents an example: labour-intensive industries, many small scale and located in the rural areas, were the spearhead of the industrialisation efforts so long as the labour surplus remained (see Fei, Ranis and Kuo, 1979). Only as the labour surplus has been exhausted has the economy started to move towards more capital-using and sophisticated technologies.

Technology does not come gift-wrapped and ready to work at 100 per cent efficiency. Its development consists in a rather unstructured process of large discoveries associated with major changes in processes and products, followed by small improvements that, when added together, often amount to as great a change in resource use and productivity as the radical innovations.[8] Its efficient use requires considerable technological capability in the recipient for installation, adaption to local conditions, operation and maintenance. The way technology develops has considerable implications for the process of TT. As Rosenberg and Frischtak (1985) state:

> In so far as technology is conceived as firm-specific information concerning the characteristics and performance properties of production processes and product designs, and to the extent that it is tacit and cumulative in nature, the transfer of technology is not as easy as the purchase of a capital good or a blueprint. It involves positive and sufficient costs, reflecting the difficult tasks of replicating knowledge across the boundaries of firms and nations; recipients would normally be obliged to devote substantial resources to assimilate, adapt, and improve upon the original technology.

For developing countries the process is usually even more difficult than for transfer among developed countries because more often the availability and quality of inputs, of experienced labour and of necessary infrastructure cannot be assumed to be the same as in the initiating country. Consequently, a considerable local technological effort is necessary to absorb the technology efficiently. Very often, the productivity of the technology falls considerably below levels




*Source*: Lall (1987c)
*Figure 13.2* Levels of technological capability

experienced in the developed country.[9] The need for such a local technological effort for efficient TT has been the theme of much writing – for example, Katz (1982), Lall (1987c), Enos (1989), Westphal, Kim and Dahlman (1985).

Moreover, it has become apparent that TT is not itself an on–off phenomenon; either it has happened or it has not. There are stages of assimilation, ranging from the machinery being dumped in the host country where it is operated at low capacity and high cost, to full technological capability being transferred, when the host country becomes able not only to operate the technology efficiently, maintain and repair it and innovate to raise productivity over time, but ultimately to design the next stage of the technology itself. The various stages of TT are shown on Figure 13.2. How far up the figure a country wants to go (or can reasonably be expected to go) depends on the particular technology in question, on the stage of development of the country concerned, especially the technological capability, and on the nature of the TT transmission – i.e., whether the form of technology transfer permits the higher-stage developments. Both DFI and licensing may prohibit major (and sometimes minor) local innovations. But in the process of development most countries are striving to mount the ladder of full assimilation for a variety of reasons: partly because higher stages permit more efficient operation of the technology; partly because the ability to operate at higher stages indicates increased local technological capability and, therefore, increased ability to assimilate other technologies efficiently and to acquire and bargain over new transfers; and partly because, in the higher stages, countries can take control over the direction of technological change.

## NEW TECHNOLOGIES

In recent years, there has been very rapid advance in two areas – biotechnology and microelectronics – with major implications for developing countries' strategy towards TT and indigenous technological efforts. This section briefly reviews developments in these industries, partly to assess developments in these important areas, but also because the industry studies illuminate the general process of TT.

### Biotechnology[10]

Biotechnology consists of the use of biological organisms for commercial activities. The history of biotechnology goes back centuries in such activities as fermentation and brewing of alcohol, bread and cheese making, but new developments in genetic engineering and other ways of transforming biological organisms in the 1970s revolutionised commercial possibilities, giving rise to a large number of applications with the development of new products and new techniques.[11] Potential applications lie in agriculture (seeds, livestock development); medicine (diagnostic kits, vaccines and drugs); food production and processing (with substitutes for natural products such as sugar, meat, soy beans); mining and pollution control. The first biotechnology firm was established in the USA in 1976. By 1981, there were over 80 new firms in the USA and several large established firms branching out into this area. In the UK, too, a sizeable number of small and medium-sized firms emerged. In Europe and Japan, developments have been mainly confined to established firms.

In contrast to the earlier seed revolution, biotechnology has been heavily privatised, with even developments in basic science being patented (see Buttel, Kenney and Kloppenburg, 1985). Stanford University patented the recombinant DNA processes and products in 1980. In that year, the Supreme Court ruled that microorganisms could be patented. The US Patent and Trademark Office first agreed to patent seeds in 1985.

From very preliminary evidence it is possible to sketch out some implications of the new technology for developing countries:

1. There will be some negative effects for primary producers, as new products substitute for their exports. An obvious example is starch-based sweeteners which substitute for sugar. In 1980, Coca Cola switched half its purchases of sugar to high fructose corn syrup. Another example is the development of 'artificial' livestock feed. These changes will reduce demand for the products currently produced by LDCs.
2. The new technology may greatly increase agricultural productivity, while economising on most inputs, including herbicides and fertilisers. Countries will have to adopt the new seeds if they are to compete, and as levels of output rise, prices will fall. For many primary products, with elasticities of demand less than 1, net revenues for producers will fall. It seems likely that the new technology will shift the terms of trade against primary producers, while, because of the heavy privatisation, the cost of importing the technology will be high.
3. Both production and consumption characteristics of the new technologies are likely to be mainly in line with developed country demands and conditions. Production scale of bioprocesses is large and growing,[12] and capital intensity is high relative to traditional methods of food processing. The very small producers in the informal sector will find it difficult if not impossible to get access to the processes, yet demand for competing products they produce is likely to be reduced. Thus the adverse developed country – developing country terms of trade effect will probably be reproduced between formal and informal sectors within countries. For the USA it has been predicted that the technology will further accentuate the trend towards large-scale farming and increase the degree of vertical coordination and control (US Congress Office of Technology Assessment, 1986). These effects are likely to be greater in developing countries, where the typical farm size is much smaller and the degree of vertical integration less. It is likely, unless major modifications are made, that the technology will tend to worsen income distribution in countries adopting new technology. For example, a study of the production of a single cell protein for animal feed in Nigeria suggested that if there were gains, the major beneficiaries would be poultry farmers and feed millers and consumers of poultry and eggs, all of whom are in the

upper-income groups; the losers would be the current producers of poultry feed (i.e., small farmers producing vegetable protein).[13]

4. There will be major consumer benefits – in terms, especially, of more and better food, and improved medicines. But to realise these benefits fully it will be necessary for the research to be adapted to the needs of the country.
5. The biotechnology story presents a strong argument for developing countries to 'get in on the act' and to do some R and D of their own. Independent R and D will help to hold down excessive costs of TT and to ensure that the research responds to their own needs and conditions. But evidence from developments in the advanced countries suggests that it may be difficult for many countries do effective research in this area. Developments in the USA and UK have shown very strong links between basic research at the universities and applied work within companies (see Table 13.1). Such links are much less well developed in most developing countries. Moreover, the cost of the research has been high, relative to the budgets of many developing countries. Monsanto's budget for research on the life sciences in 1985 was $270 million. The smaller companies have spent less, but still employ large numbers of Ph.Ds. A synergistic relationship has been identified between specialisation on new biodevelopments, microprocessing and marketing and distribution (Fransman, 1986a). Competitive success requires all three, which can be achieved by joint ventures or close collaboration or by uniting the three specialisations in a single firm. Many developing countries have too 'thin' an industrial structure to operate effectively over such a large area.
6. It seems likely, therefore, that countries that are mainly primary producers, that lack flexibility in terms of diversification potential, and that do not have the capacity to enter the field themselves may suffer some major losses as a result of the technology and will have to pay heavily for its use. The net gains are likely to be small. In contrast, countries able to diversify out of primary products, and to establish some local R and D capacity will be able to use the technologies to raise productivity and employment.

### Microelectronics[14]

The microelectronics revolution was based on scientific and technological breakthroughs in transistors and semiconductors. It represents a technology revolution because it has not only created a new

*Table 13.1* Agricultural biotechnology venture capital firms: selected University-based researchers, financial linkages, and areas of research

| *Company* | *Principal university-based researcher affiliation* | *Financial linkages* | *Areas of research* |
|---|---|---|---|
| Agrigenetics | Timothy Hall, U. of Wis.<br>John Kemp, U. of Wis./USDA<br>Vernon Gracen, Corneil | Hoffman–La Roche<br>Kellogg Co.<br>Rothschild Bank | Seed-related biotechnologies |
| Advanced Genetics Science | Lawrence Bogorad, Harvard<br>Milton Schroth, U. of Calif. Berkeley | Rohm & Haas<br>Hilleshog | Cloning of disease-resistant potatoes |
| International Plant Research Institute | Oluf Gamborg, Prairie Regional Laboratory, Canada<br>(Formerly) Martin Apple, U. of Calif., San Francisco | Davy–McKee Corp.<br>General Foods<br>Bio-rad Laboratories | High-yielding potatoes, saline-resistant wheat, virus-free cassava |
| Zeocon Corp. | | Sandoz (formerly Occidental Petroleum) | Soybean and cotton breeding |
| Calgene | Raymond Valentine, U. of Calif; | Allied Chemical (20%) | Plant genetics |
| Genetic Engineering Co. | Davis Edwin Adair, U. of Colo.<br>Thomas Wagner, Ohio U. | Johnson & Johnson | Animal reproduction |
| DNA Plant Technology Co. | Norman Boriaug, Texas A&M<br>Philip Ammirato, Columbia<br>Melvin Calvin, U. of Calif. | Campbell Soup (40%)<br>Koopers Co.<br>General Foods | Tomatoes, tobacco, forestry products |
| Molecular Genetics | Anthony Faras, U. of Minn.<br>Charles Green, U. of Minn.<br>Lynn Enquist, NIH | American Cyanamid<br>Moorman Manufacturing<br>US Dept. of Defense | Corn, scours prevention, and non-agricultural applications |

*Sources*: Buttel, Kenney, and Kloppenburg (1985).

cluster of industries to produce the new producer goods and a further cluster of industries to produce the consumer goods that microelectronics makes possible, but its applications potentially extend throughout production and affect much of consumption. The potential effects are thus more far ranging than those of biotechnology. The full effects on developing countries have not yet been felt, and, as pointed out in James's survey, many of them are unresearched. This brief overview is therefore necessarily incomplete.

Like biotechnology, the microelectronics technology is a proprietary technology: 'whether final goods or components, vital technical information regarding design engineering specification, process know-how, testing procedures etc. is proprietary in nature, covered by patents or copyrights, or closely held within various electronics firms from developed countries' (O'Connor, 1985a).

The first direct effects of the revolution on LDCs was the location of production for export in the Third World. While production of mainframe computers was mainly located in the advanced countries, production of smaller computers, more subject to price competition, was shifted to low-wage locations 'as a short-term survival strategy' (O'Connor, 1985b). Countries were selected on the basis of low wage costs, political stability, labour docility, and government incentives, including the availability of low-priced infrastructure (Nayyar, 1978; Ernst, 1985). These factors led to the initial choices of Singapore, Taiwan, and S. Korea. Subsequently, there was some relocation, as wages rose in S. Korea and Taiwan, to Malaysia, the Philippines and Thailand.

Location of production for local and regional consumption followed. The countries concerned were mainly middle-income. Three-quarters of US investment overseas in the industry in the Third World was concentrated in 12 countries.[15]

The export-oriented investments were more associated with direct foreign investment than firms producing for the local market (ESCAP, 1979). Evidence from Brazil is that DFI was associated with larger firms in developed countries, licensing with smaller firms (Tigre, 1985). Both these findings echo findings for TT in general (See Reuber, 1973; Lall, 1987c). It also appears that in this industry, as elsewhere, firms were reluctant to license the more recent and advanced technologies:

> Japanese firms prefer to transfer know-how only for small portables, using older technology in tubes and semiconductors. Japanese

producers have been unwilling to provide Korean firms with technical know-how for new products such as VCRs and video discs (Clarke and Cable, 1982).

Sub-contracting by MNCs was used for the transfer of more standardised and unsophisticated products, especially where there was a strong risk of fluctuations in demand which could be offloaded to the LDC firm (Plesch, 1979).

Microelectronics has been an area where proprietary rights have been discarded by some firms in the more technically advanced LDCs (Brazil, Taiwan and S. Korea), with reproduction of goods produced by the MNCs by unlicensed firms. This was made possible by outside sourcing which disclosed technical information to supplying firms (see O'Connor, 1985a; 1985b). The longer-term implication of this form of TT has not been investigated. It has a parallel in some pharmaceutical industries which do not respect proprietary rights and is one of the major factors underlying the recent demand to extend the GATT to cover intellectual property.

The use of microelectronics in production saves on one or another or all inputs, including skilled and unskilled labour, energy, materials and capital, while it also can make possible new products and better product quality of existing products. Where all inputs are saved, the new technology dominates and is efficient at any wage level, and consequently early adopters will be able to outcompete non-adopters. In these industries, LDCs will lose any competitive advantage unless they also introduce the new technology. But for some industries – as is the case with textiles and garments – the new technologies save on labour and materials, but use capital, so that whether they are economically efficient depends on relative prices. Studies of computer-controlled machine tools show that there is a significant saving in skilled labour (James, 1986). As noted above, microelectronics also permits smaller-scale production in some sectors. Product quality is generally improved. Consumer products generally have high-income characteristics.

In some respects, then, the production characteristics associated with microelectronics are more appropriate than previous technologies – especially with respect to scale and savings of skilled labour, energy and materials – while the product characteristics are typically inappropriate. Moreover, adaptations can make the technology more appropriate. In Taiwan, product innovations have led to reduced performance of numerically controlled machine tools which was more than compensated for by reduction in price (Fransman, 1986b). Efforts to apply microelectronics to improve traditional technologies – in what has been termed 'technology blending' (Bhalla and James, 1986) – have produced some major improvements in productivity, including, for example, the use of electronic load controllers in microhydro projects.

However, the introduction of the technologies requires certain new skills (of design, maintenance and management, Hoffman, 1985) and complementary infrastructural facilities, including telephone systems and reliable power supplies. Deficiencies in these factors in the less developed countries prevents the widespread adoption of the technologies (Munasinghe, Dow and Fritz, 1985).

Taking these considerations together, it appears that the more advanced developing countries, with a good basis of skills and infrastructure and a flexible labour force, may be in at least as good a position to adopt the new technologies as the developed countries; the production characteristics of the technologies are not inappropriate, and the consumption characteristics can potentially be adapted to the country's needs. For these countries, the technologies will increase their productivity and their international competitiveness. But the less developed Third World countries, with inadequate skills and infrastructure, low labour productivity and lack of capital resources, will find it difficult to adopt the new technology. They are likely to suffer a deterioration in international competitiveness *vis-à-vis* both developed countries and the more advanced developing countries.

## POLICIES TOWARDS TT

The previous two sections have indicated the broad dimensions of TT transfer relevant to LDCs in determining their policies. In summary, developing countries face a technology market that is typically oligopolistic, especially for the more recently developed technologies. While some technologies are available at low cost, many, again especially the latest, are subject to tight control, and a high cost is exacted. The characteristics of the technology are often inappropriate for the production and consumption needs of poorer countries, but this inappropriateness can be substantially lessened by making appropriate choices and adaptations of the technologies available. To operate the technologies efficiently and to adapt them to their own needs, it is essential for LDCs to build up technological capacity. Despite the problems associated with TT, much modern technology is highly efficient and offers poor countries huge potential for improving their productivity. As seen in the previous section, these broad dimensions characterise the 'new' technologies as well as mainstream TT.

Given the objectives of equitable growth and the development of technological capability, developing countries' policies towards TT should therefore be designed to improve the terms of TT, enhance the efficiency of the transfer, and increase the appropriateness of the technology in use. There may be some trade-off between these aims, and countries will then have to decide where their priorities lie. Three types of policies are relevant: direct regulation of the form and terms of TT policies to build up local technological resources; and general policies towards the economic environment. These will be discussed in turn.

**Direct Regulation**

An important issue is whether countries should intervene on the form of technology transfer, either by providing special incentives for DFI or by limiting the areas in which it may operate, requiring MNCs to participate in joint ventures or permitting only arm's-length TT. Different countries have adopted each of these approaches: for example, many countries provide generous tax incentives to encourage DFI, while others only permit minority ownership in some or all industries. Singapore is a successful example of the first approach; Japan, historically, and S. Korea until recently, have mainly encouraged arm's-length TT, again successfully. Less successful examples can also be found of both approaches.

The most appropriate approach partly depends on the stage of development. In the early stages countries may lack the capacity to put the package together themselves, and therefore may need to rely on DFI. But at intermediate stages of development, there is considerable evidence that arm's-length transfer is associated with considerably greater technological learning than DFI.

In a survey of six Asian country studies, Enos (1989) repeatedly found that there was greater local technological effort associated with non-equity transfers. For example, in Indonesia it was found that 'the degree of technological mastery is greater in the national companies' (Thee, 1987); in S. Korea, Lee (1987) found that local effort was greater in local firms; in Malaysia, where there was heavy reliance on DFI, it was found that the technology was not transferred to non-Malaysians; in Thailand, Santikarn (1987) showed that the technology was transferred more effectively where foreign equity was absent. However, Pack (1987) found that in a Kenya–Philippines comparison of the textile sector, total factor productivity was higher in Kenya, and he attributed this to the presence of international managers of high quality, associated with DFI.

The development of technological capability is shorthand for a complex set of events, including training, experience, local R and D and diffusion of the technology throughout the economy. While the record is mixed, the MNCs appear to perform adequately on training (UNCTC, 1987), but are relatively weak on R and D and on generating sufficient local experience in management, technology choice and innovation. There is evidence for US MNCs only for 1982. This showed that they did very little R and D outside the USA (9 per cent of a total of $41 billion), and of this a tiny fraction (0.6 per cent) was spent in developing countries (UNCTC, 1987). Country comparisons of R and D and innovation among foreign and local firms generally show somewhat more innovative activity among local companies, though there are cases where MNCs have undertaken significant amounts of R and D in developing countries.[16]

The nature of the industry is also relevant. On the one hand, in the more sophisticated industries it may be impossible to secure the technology without DFI, as noted earlier. On the other, the ability to put the package together without DFI will be less – for any stage of development – the more sophisticated the technology. Also where the technology is changing rapidly, it may be difficult for local firms to get access to the latest developments. Consequently, S. Korea encouraged DFI for the more sophisticated industries and for export industries, where market access can provide another reason for having DFI.

The extent of diffusion of the technologies – including knowledge about the hardware and operating skills – varies with the type of industry. Export industries established in export-processing zones have low diffusion due to the nature of the zones with limited linkages to the rest of the economy and also the rather standard low-skill technologies involved; the more technologically sophisticated activities are concentrated in the advanced countries. However, a comparative study of diffusion of innovations in S. Korea exhibited that both subsidiaries of MNCs and local firms showed a

*Table 13.2* Frequency of selected restrictive clauses in contracts in four Southeast Asian developing countries, %

| *Restrictive clauses relating to* | *Republic of Korea* | *Malaysia* | *Sri Lanka* | *Thailand* |
|---|---|---|---|---|
| Export | 24.0 | 30.4 | 41.4 | 27.2 |
| Purchase of inputs | 16.5 | 14.6 | 22.1 | 8.3 |
| Confidentiality | 80.5 | 54.0 | 37.1 | 45.6 |
| Rights granted to recipients | 49.0 | 44.8 | – | 50.3 |
| Manufacture of competing or similar product | 11.5 | 10.3 | – | – |
| Cease-use clauses | 33.5 | 20.2 | 21.4 | 19.3 |

*Source*: ESCAP/UNTC (1984)

high rate of diffusion (Westphal, Rhee, and Pursell, 1981).

A second consideration is the price of the technology transferred in different ways. Research in the 1970s showed that DFI can be associated with very high costs, especially if over-invoicing is allowed for, and particularly in the more oligopolistic industries (Vaitsos, 1974; Helleiner, 1981a; Murray, 1981). The use of joint ventures may not alter the costs significantly compared with DFI. However, technology licensing can also be costly, involving not only explicit payments but also various clauses restricting the freedom of technology recipients. Table 13.2 shows the restrictive clauses found in a 1977 survey. Some of the restrictions inhibit effective TT and technology diffusion. For example, in Indonesia it was found that restrictions were imposed on major product innovations (Enos, 1989). 8 per cent of technology contracts to Thai firms were found to forbid the duplication of know-how or reverse engineering (Santikarn, 1987). Such restrictions may, of course, also be present (but with no need for any explicit clause) in DFI or joint ventures. But the evidence suggests following a strategy of licensing alone is not enough to ensure that monopolistic rents are not being levied.

The costs of TT vary inversely with stage of development according to a UN study of eight Asian countries (quoted in Enos, 1989). They are also greater the more complex the technology. The highest fees are to be found in petroleum, chemicals, metals, machinery, electrical equipment and electronics.

A third consideration is the appropriateness of the technology and products transferred. Research into the relative capital intensity of technology adopted by MNCs and local companies on balance shows little difference (and in some cases a difference favouring the MNC) if one compares production of the same product, at similar scale (see Pack, 1976; ILO, 1972; Wells, 1973; 1979; Reuber, 1973). However, more significant differences arise from differences in choice of product and of scale, with the MNC on average being associated with more 'high-standard' and capital-intensive products, and producing on a larger scale than local companies (see examples in Stewart, 1987).

Over the past twenty years, Third World MNCs have developed on a quite substantial scale, generally concentrated on mature technologies in well-established industries (see Lall, 1983; Green, 1988). On balance they have a better record on cost of technology transfer and on appropriateness of products and techniques than advanced country MNCs.[17]

In conclusion, there seem to be strong reasons for preferring arm's-length 'unpackaged' TT, from most points of view, especially in relation to building up local technological capability. But this may not be a realistic possibility for the more sophisticated technologies, nor an efficient alternative for countries at an early stage of development, with weak domestic technological capability. For the latter, Third World MNCs may have more to offer at less cost than advanced country MNCs.

Joint ventures represent an intermediate option between DFI and licensing. Whether, in practice, the joint venture approximates more nearly DFI or arm's-length TT depends on the specific conditions of the joint venture and the capabilities and bargaining power of the two partners. In the less-developed countries, joint ventures appear to be very similar to DFI.

In the 1970s a number of countries developed regulatory policies designed to control the price of TT, reduce restrictive clauses and encourage local technological development.[18] These policies generally require draft technology contracts to be submitted for government approval. Regulations may be imposed on the import of technology where there is a local alternative, on the extent of royalty payments and of restrictive clauses, and on the duration of the contract. Evidence may also be required that the licensee has made an adequate search for alternatives and that the contract will be associated with training and local R and D.

The evidence suggests that these regulations had a substantial effect on the formal terms of TT, without affecting the level of transfer, and that some countries made 'substantial savings of foreign exchange'.[19] There was a reduction in rates charged and of restrictive clauses, while the number of contracts was maintained or increased in all regulating countries, except for Argentina. However, it is not known how far the regulations were circumvented informally. Collusion between licensee and licensor can make regulation ineffective.

Regulations of this sort have the effect of increasing the bargaining power of the recipient firm. In conditions where markets are imperfect and oligopolistic rents are being earned, such regulations ought to be effective in reducing costs without adversely affecting quantity. Taxation is another mechanism which can be used to reduce excessive payments for TT (see Stewart, 1981).

Regulations have also been used to protect local technological efforts, by restricting imports. India followed a very restrictive policy, which led to a significant build-up in local technological capability. Some of the technologies that resulted were internationally competitive, as indicated by significant technology exports. According to Lall: 'low reliance on imports of technology in the process of industrialization . . . contributes to buildup of a diverse and deep technological capability' (Lall, 1985). However, India fell behind the international technological frontier in many areas, and this had adverse effects on the competitiveness of India's industries (Lall, 1985). Japan and S. Korea also regulated technology imports, but much less comprehensively than India, importing the initial technology, learning to reproduce it locally, and subsequently restricting imports when local technological alternatives became available. R and D and other technological efforts were thus complementary to technology imports in the policies of Korea and Japan, in contrast to the competitive policies in India. While the Indian policies were effective in boosting technological capability, they had a much higher economic cost than the policies of Korea and Japan.

**Policies to Build Up Local Technological Capacity**

Much research suggests that active local efforts are needed to ensure efficient TT, with consequent learning effects. Thus, according to Santikarn (1987):

> Ownership and control by nationals is not, however, sufficient to ensure success in absorbing technology . . . The degree of

> success . . . depends upon the ability, awareness and management skills possessed by recipient enterprises, its investment in human resources through training and upgrading of skills.

Following a detailed survey of TT and learning, Bell (1986) emphasised that learning does not take place automatically, but requires a conscious local effort.

High levels of human capital are essential for this process. Government policy to build up education in general and scientific and technical education in particular has been a vital element in the success of technological development in Japan, S. Korea and Taiwan, and its absence one of the major missing factors in many African countries. Comparing Korea, Argentina, Brazil, India and Mexico, Westphal, Kim, and Dahlman (1985) conclude:

> What stands out about the educational pattern are the high proportion of postsecondary students abroad, the high secondary enrollment rate and the high percentage of engineering students among postsecondary students . . . by the late 1970s South Korea had by far the highest percentage of scientists and engineers.

In addition to support for general education, government support is needed for R and D institutions. As noted above, the public goods aspects of R and D make this essential. Local R and D is needed to adapt products and techniques to local conditions, especially to generate appropriate technologies. The biotechnology and microelectronics cases illustrated how important local efforts are if the revolutions are to be harnessed to local needs.

However, it is not a matter of supporting any old R and D. Much developing country R and D has produced 'white elephants' (Beranek and Ranis, 1978), duplicating the research efforts of advanced countries rather than aiding industry to adapt imported technologies, or upgrade local technologies. Too little is known about the inner workings of R and D institutions, the motivations of scientific personnel and how best they can be channelled to useful activities. It appears that close ties with users, a clear, defined mandate and high-class personnel are essential. There are successful 'models' – including notably the Korean Institute of Technology, the Madras Leather Institute and the Electronics Institute in Taiwan. More research is needed to learn from these and other successes.

**General Government Policies**

The general policy environment is of major significance to the effectiveness of TT. It can affect the cost of the transfer, the efficiency of its use, learning effects and the appropriateness of TT.

The cost of the transfer in an oligopolistic market is in part a function of how much consumers are prepared to pay. Consequently, if the market is highly protected against internal and/or external competition, high rents can be levied by the producer, and part of these rents may not be retained in the country, but transmitted to the technology supplier. This certainly occurs in the pharmaceutical industry, and it is likely to be a phenomenon associated with bioprocesses. A competitive environment would thus be associated with lower costs of technology imports. This can be achieved through internal competition policy or through trade policy, where competition from imports or from other countries' goods in export markets may reduce rents.

However, in some industries with large economies of scale and learning economies, an excessively competitive environment may prevent what would ultimately be desirable production activities from taking place (this is elucidated in Pack and Westphal, 1986). Moreover, the desire to promote local technological activity may justify monopolistic or oligopolistic production, given the strong externalities. On the other hand, competitive pressures may be needed to provide an incentive to increase technological efforts and raise productivity. There can be conflicts, therefore, but these may be moderated by policies reducing the rent potential of such monopolistic activities. This appears to have been achieved in Korea by strong regulatory pressures (see Pack and Westphal, 1986; Enos and Park, 1987). Without such regulatory pressures, local technological activity can be misdirected – as in the case of India, according to Lall – where considerable local technological efforts has resulted in some rather inefficient technologies, compared with international standards.

General government policies are extremely important in influencing choice of technology and the direction of local technological change (see Stewart, 1987; Stewart and Ranis, 1990). Policies towards factor prices (e.g., tax incentives for investment, wages policies), credit markets, international trade, income distribution and product standards help determine the choice of products and techniques made by individual enterprises, and also the composition of units (i.e., the proportion of total investable resources controlled by different types of decision-makers). In many countries, macropolicies systematically favour inappropriate technologies.[20] Policies that support appropriate products and labour-intensive techniques will lead to a greater use of older more standardised technologies; these technologies are thus likely to be more accessible to arm's-length transfer, to be available from a wider range of technology sources, including developing country sources, and to be transferred at lower prices than the technologies associated with more capital-intensive strategies.

**Policies Toward the Environment and TT**

It is now generally agreed that excessive environmental degradation can occur if investment decisions are motivated only by profit or output maximisation, without consideration of environmental effects. Developing countries can use policies regulating the import of technologies, in addition to policies applicable to all productive activities in the economy, to moderate environmental destruction. However, problems arise in devising appropriate standards (as well, of course, as in enforcing them). Being poorer, countries may be prepared to accept lower standards than in the rich countries, especially if this permits more rapid elimination of poverty, which is itself a major cause of environmental problems. However, although there is a strong case to be made for different standards in developing countries than in advanced countries, this does not mean there should be no standards – the very rapid rates of industrialisation in some countries, technological developments and the potential export of 'dirty' technology from developed countries, make a strong case for the imposition of environmental standards.

A further problem is caused by the fact that some of the environmental costs associated with developing country growth are imposed on the world at large and not solely on the country concerned. An obvious example is the 'greenhouse' effect resulting from use of carbon fuels. Here global action is needed with the advanced countries supporting action by developing countries with research, subsidised technologies in 'clean' fuels, and finance. For world environmental problems, the technology-exporting countries can contribute by imposing export controls on dirty technologies.

## SOME CONCLUSIONS

TT is an interactive process between technology suppliers and technology users. Developing countries have a difficult balance to strike in choosing which technologies to import and how to import them. On the one hand, they need the productivity increases modern technologies confer. On the other hand, they do not want to pay an excessive price, which the oligopoly position of suppliers permits; they want to avoid the more inappropriate characteristics of imported technology; and they want to build up their own technological capacity, which can be inhibited by excessive dependence on imports.

Appropriate technological strategies depend on the stage of development. The least developed countries have no choice but to import technology, often in a packaged form. But they can avoid paying too high a price by sticking to older technologies and searching for Third World suppliers, while developing their own human capacities by education and training. These older technologies often have more appropriate characteristics. However, the highly efficient 'new' technologies create problems for these countries because they add very greatly to productivity, but require skills and infrastructure that the countries lack.

For countries with more industrial experience, importing technology in unbundled form has considerable advantages from the point of view of learning effects and the creation of technological capacity. It may not be possible for very recent technologies as suppliers may refuse to sell the technologies in this form, and in some cases the management and scientific requirements may be too great. But as countries acquire experience with the more mature technologies, they also acquire the expertise to manage later technologies. The example of biotechnology underlines the need for local R and D capacity to adapt technological advances to local conditions.

Middle-stage developing countries with high levels of education and skills and a significant R and D capacity are in a very good position to exploit the new technologies effectively. Indeed, given their adaptable workforce and lack of cultural rigidities, they may be able to use the technologies more effectively than the advanced countries. In so doing, they present a competitive threat both to the advanced countries and to the least developed countries. For the former, their lower wages and more disciplined workforce may mean that their unit costs are potentially considerably lower than in the advanced countries in many industries; the inability of the least developed countries to apply some of the new technologies effectively (e.g., computer-aided design in textiles, or biotechnology in primary products) may mean that they become relatively high-cost producers who can compete only with very adverse movement in the terms of trade.

Recent advances are creating a new technological division in the world economy; the late latecomers will find it increasingly difficult to take off industrially because of these technological advances and the success of the NICs and near NICs in making use of them.

NOTES

1. See, eg., Little (1982), Lal (1983), and World Bank *World Development Reports*, but see also comments by Stewart (1985b) and Toye (1985).
2. For an estimate of the costs of communication in some industries see Teece (1976).
3. An intermediate solution is sometimes adopted in which companies are encouraged to collaborate on R and D (or even to amalgamate) so as to internalise major externalities. This appears to have been the policy promoted by MITI in Japan, and also in some sectors (e.g., planes, electronics) in the USA and Western Europe.
4. The precise distinction between what is basic and what is applied, which has always been unclear, is getting more blurred; recently patents have been granted in what would appear to be basic areas, with respect, for example, to biotechnology and superconductivity.
5. In the UK, for example, firms with less than 1000 employees account for only 3 per cent of R and D expenditures, but a very much larger proportion (more than 30 per cent) of 'significant innovations commercialised in the UK'. Firms with more than 10,000 employees account for over 80 per cent of R and D and 47 per cent of significant innovations. In the USA the top 100 firms account for 90 per cent of R and D expenditure, and 60 per cent of a measure of technological activity (Pavitt and Patel, 1988).
6. Surveys of firms' R and D efforts in developed countries typically find that about three-quarters is spent on efforts intended to bring about product innovation, with one-quarter devoted primarily to process innovation (see, e.g., Gustafson, 1962). In developing countries most research suggests that a smaller proportion of efforts is mainly devoted to product innovation. Of course, the distinction is not hard and fast since some firms' products are in fact other firms' processes, while much innovation in processes results in product modification and vice-versa.
7. Enos (1989) estimates that DFI and joint ventures accounted for only 14.7 per cent of India's technology acquisitions between 1969 and 1979

and 48.3 per cent of the Philippines'. For S. Korea they accounted for 27.4 per cent of the number of approvals of technology imports between 1962 and 1981. (These figures exclude purchases of capital goods as a source of technology.)
8. Powerful empirical support for this view is provided by Hollander (1965) and the ECLA/IDB/UNDP/IDRC studies in Latin America.
9. See, e.g., Teitel (1984), who shows major divergences in productivity between the USA and Latin American countries.
10. This section draws heavily on the work of Fransman (1986a) and others in the New Technologies Centre Feasibility Study.
11. Two basic scientific discoveries lie at the heart of the revolution: recombinant DNA technology, which allows new genetic combinations (applications include pharmaceuticals, chemicals, food processing, improved mining techniques and pollution control), and cell fusion technology, which permits the desirable properties of different cells to be combined into a single cell (applications include improved diagnostic techniques). Improvements in bioprocess technology have also resulted in the large scale use of biological processes.
12. See evidence from Cellnet quoted in Fransman (1986b).
13. See Okereke (1988). In fact it is questionable whether there would be net gains, as on present estimates the feed is expected to cost 10 per cent more than traditional feed, but supplies might be of higher quality.
14. This section draws heavily on James's (1986) and on Soete's (1986) papers for the New Technologies Centre Feasibility Study.
15. India, Brazil, Mexico, Colombia, Malaysia, Hong Kong, the Philippines, Singapore, Taiwan, S. Korea and Thailand.
16. Two examples of major local innovations by MNCs in Argentina are reported in UNTC (1987). In the Brazil computer industry, high learning effects from DFI were reported in James (1986).
17. In a study of Thailand, for example, Lecraw (1977) found that Third World MNCs were significantly less capital intensive than those from advanced countries.
18. See United Nations, TD/B/C.6.48; United Nations, TD/B/C.6/55; Correa (1981).
19. UNCTC (1987) p. 63. Policies to regulate TT to Japan also had negligible effects on the inflow of technology. According to Ozawa (1981): 'Foreign licensors did complain about the government's intervention, but kept supplying technology – a clear sign that the prices they received were acceptable to them.
20. See Stewart (1987) and Stewart and Ranis (1990) for evidence of this in a large number of countries.