CHAPTER VII

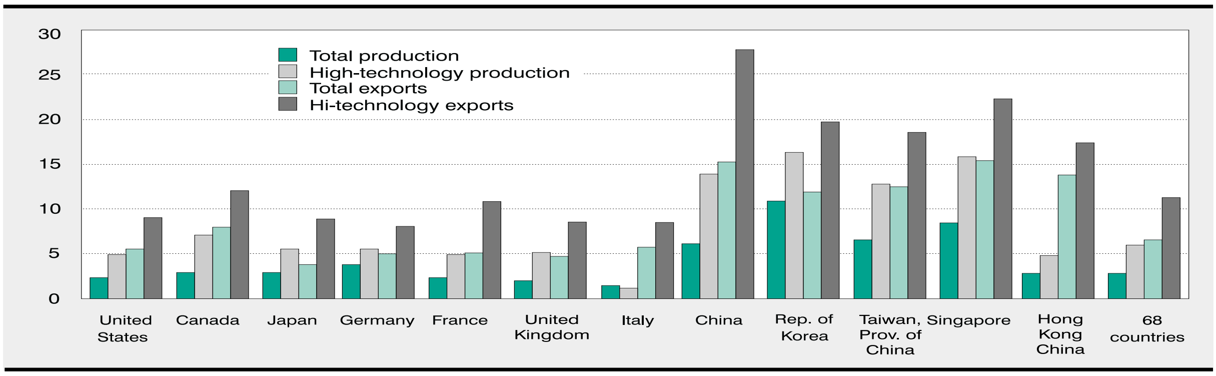
ENHANCING TECHNOLOGICAL CAPABILITIES

A. Technology, learning and development

Technology has always been important to economic wellbeing; the current technological context makes it critical to development. This context, which some call a new "technological paradigm" (Freeman and Perez, 1988), is rapidly transforming all productive systems and facilitating globalization (chapter V). The concept of globalization may not be new – but its content is now very different (Baldwin and Martin, 1999): the pace of technological change, and within it the role of information-based technologies, is unprecedented.

Figure VII.1. Growth rates of total and high-technology production and exports, 1980-1995

(Percentage)



Source: UNCTAD, based on NSB, 1998, appendix table 6.5.

The impact of technological progress is not uniform. *Product* innovation may be used to encourage consumption; and, with rising incomes, consumer demand becomes more differentiated – which further stimulates product innovation. *Process* innovation can dramatically cut the costs of production. Some new technologies are opening entirely new areas of activity. The application of information technology is a good example. In most developed and newly industrializing countries, activities with greater innovation potential (and hence the output of high-technology industries, including in the services sector) have grown faster than that of others (figure VII.1). Exports have risen faster than total production – a manifestation of globalization

– and, within exports, high-technology products have grown more rapidly. Sustained economic growth hence increasingly calls not only for the application of new technologies, but also for a shift in the productive structure from low- to high-technology activities.

An analysis of FDI and technology in developing countries has to take account of this changing context. The developing world is facing not just rapid technical change, but also shrinking economic space and dramatically intensifying competition. The parameters of competition are changing with the nature of the innovation process and the organization of production (Lall, 1998; Ernst, Ganiatsos and Mytelka, 1998a). In some (largely traditional) activities, it may be possible to remain competitive with unskilled cheap labour making homogeneous products. In most modern activities, however, competitiveness entails new, more rapid product innovation, flexible response, greater networking and closely integrated production systems across firms and regions (what Best, 1990, calls the "new competition"). The knowledge intensity of shop-floor, process and product engineering has increased considerably. The leaders of technological change (most of them transnational) are evolving new strategies in response. Apart from investing heavily in innovation, they are moving their technological assets around the world to match them to immobile factors, entering new alliances and reorganizing production relations.

The new competition places stringent demands on governments. These demands vary by level of development, of course. Industrial countries, generally speaking, focus on achieving – or even pushing beyond – frontier innovation. They seek to improve their "national innovation systems".[1] Developing countries, in general, are more likely to focus on adapting existing technologies more effectively. Nevertheless, firms in a number of developing countries are among the innovators, especially in emerging areas that offer niches of opportunity. Examples include biotechnology, information technology or new areas of services industries. In every case, countries have to cope with the new competition and changing flows of knowledge and productive factors – all in a far more open economic environment in which there is a "renaissance of capitalism" (Dunning, 1998a). This new competition is the *first reason* why the analysis of FDI and technology in host developing economies today must differ from that, say, of three or four decades ago.

The *second reason* is that our understanding of technology has evolved. Much of early development thinking assumed technology transfer and diffusion in developing countries to be relatively easy, and framed the analysis of TNCs in that context. The main need was thought to be for physical investment. Technologies were transferred "embodied" in new equipment or in patents or blueprints; their efficient use was, if considered at all, taken as given. The structuralist approach supported industrial development behind protective barriers; the neoclassical approach favoured market-driven resource allocation with free trade and international investment flows. Both assumed that countries passively received and deployed technologies from abroad, and did not differ in their ability to use technology. Thus, there was a tendency towards uniform development strategies for all developing countries. In the area of technology, policy and research attention focused on modes of technology transfer and its defects. It largely ignored how well countries coped with the technologies they imported (see for example Katz and Bercovich, 1993; Katz, 1998). Moreover, the "soft" side of technology transfer and absorption – organization and managerial practices, tacit knowledge and the like – was neglected.

The consequences of neglecting technology absorption are evident under both strategies. Import substitution, by removing the competitive spur to learning, led to technological inefficiency and lags. Liberalization helped technology development in the countries that had built up a strong base of absorptive capabilities, but by ignoring the needs of costly learning and by – incorrectly - assuming efficient markets, delayed or hindered it in others. There is growing divergence rather than convergence in national capabilities: "getting prices right" is thus not a sufficient condition for sustained development (World Bank, 1998; Stiglitz, 1998a). There is now ample evidence that the technological leaders in the developing world adopted specific strategies on technology, different from both classic import substitution and free markets.

The discussion of FDI and technology needs a sound understanding of how firms in developing countries actually become proficient in using technology. For this, we turn to recent research on micro-level technical change (Ernst, Ganiatsos and Mytelka, 1998a; Lall, 1999a). This research, based on evolutionary theories of technological change (Nelson and Winter, 1982), shows why importing and mastering technologies in developing countries is not as easy as earlier assumed. Technology is not sold like physical products, in fully embodied forms; nor does it flow by osmosis when agents are exposed to more advanced systems of knowledge. It has important *tacit elements* that need effort to master. The process is incremental and path dependent (box VII.1). It often faces an uncertain environment where the skills, information, networks and credit needed are not readily available. Enterprises have to interact intensively with other agents. All these features mean that technology development faces extensive coordination problems, externalities, missing markets and cumulative effects.

Box VII.1. Ten features of technological learning

1. Technological learning is a real and significant process. It is conscious and purposive rather than automatic or passive. Firms using a given technology for similar periods need not be equally proficient: each would travel on a different learning curve according to the intensity and efficacy of its capability-building efforts.
2. Firms do not have full information on technical alternatives. They function with imperfect, variable and rather hazy knowledge of technologies they are using.
3. Firms may not know how to build up the necessary capabilities — learning itself often has to be learned. The learning process faces risk, uncertainty and cost. For a technological latecomer, the fact that others have already undergone the learning process is both a benefit and a cost. It is a benefit in that they can borrow from the others' experience (to the extent this is accessible). It is a cost in that they are relatively inefficient during the process (and so have to bear a loss if they compete on open markets).
4. Firms cope with uncertainty not by maximizing a well-defined function but by developing organizational and managerial satisficing routines (Nelson and Winter, 1982). These are adapted as firms collect new information, learn from experience and imitate other firms. Learning is path-dependent and cumulative.
5. The learning process is highly technology-specific, since technologies differ in their learning requirements. Some technologies are more embodied in equipment while others have greater tacit elements. Process technologies (like chemicals) are more embodied than assembly technologies (machinery or automobiles), and demand different (often less) effort. Capabilities built up in one activity are not easily transferable to another.
6. Different technologies have different spillover effects and potential for further technological advance. Specialization in technologies with more technological potential and spillovers has greater dynamic benefits than specialization in technologies with limited potential.
7. Capability-building occurs at all levels — shop-floor, process or product engineering, quality management, maintenance, procurement, inventory control, outbound logistics and relations with other firms and institutions. Innovation in the sense of formal R&D is at one end of the spectrum of technological activity; it does not exhaust it. However, R&D becomes important as more complex technologies are used; some R&D is needed just for efficient absorption.
8. Technological development can take place to different depths. The attainment of a minimum level of operational capability (know-how) is essential to all activity. This may not lead to deeper capabilities, an understanding of the principles of the technology (know-why): this requires a discrete strategy to invest in deepening. The deeper the levels of technological capabilities aimed at, the higher the cost, risk and duration involved. The development of know-why allows firms to select better the technologies they need, lower the costs of buying those technologies, realize more value by adding their own knowledge, and to develop autonomous innovative capabilities.
9. Technological learning is rife with externalities and interlinkages. It is driven by links with suppliers of inputs or capital goods, competitors, customers, consultants, and technology suppliers. There are also important interactions with firms in unrelated industries, technology institutes, extension services, universities, associations and training institutions. Where information flows are particularly dense, clusters emerge with collective learning for the group as a whole.
10. Technological interactions occur within a country and with other countries. Imported technology is generally the most important initial input into learning in developing countries. Since technologies change constantly, moreover, access to foreign sources of innovation is vital to continued technological progress. Technology import is not, however, a substitute for indigenous capability development — the efficacy with which imported technologies are used depends on local efforts to deepen the absorptive base. Similarly, not all modes of technology import are equally conducive to indigenous learning. Some come highly packaged with complementary factors, and so stimulate less learning.

Source: Lall, 1999a.

More importantly, firms face learning problems: learning to use new technologies, even those existing elsewhere, requires new skills, effort and institutional change. The diffusion of technologies even in industrial countries poses challenges (OECD, 1996a); in developing countries, it is generally far more difficult. This is why simply exposing firms to unregulated markets may not lead to sufficient technological learning. Firms may not be able to bear the costs involved or link their own learning processes with those of other firms that provide them with inputs or buy their outputs and so affect their own competitiveness. (Such technological interdependence can lead to under-investment by all linked firms.) And mastering new technology is not just a once-for-all task. It is a process that requires continuous *upgrading* and *deepening* of all kinds of intellectual capital, as well as of supporting networks and institutions. Without this, countries can remain at the bottom of the technology ladder where their competitive edge lies in simple assembly or processing based on cheap labour – once wages rise they lose this edge. Thus, as they master the simpler elements of technology, they have to move into more advanced technological capabilities. As technologies change, they have to upgrade their own capabilities to remain competitive. As they gain competence in simple activities, they have to move into more advanced ones, although this process may not necessarily be linear. At each stage, learning needs new knowledge, skills and organization. At every stage, it becomes more challenging. In the new technological context, the challenges themselves become greater. The confluence of the two new analytical factors noted is that the building of new capabilities is critical to technology development in the emerging global competitive scene, even for developing countries that are not "innovators".

The enterprise is at the core of technology development, but it operates within a system. The main elements of this system are market and competitive signals (the incentive regime), factor markets and institutions (Lall, 1992). This interacting "triad" comprises the structure within which firms learn and create technology. Random firm-level factors aside, systems differ in their ability to stimulate, support and coordinate technological effort. Systemic differences arise from how efficient the various markets and institutions are, and the extent to which governments can improve them when they are deficient. The risks of market and institutional failure always exist and they are particularly high where learning, information, coordination and externalities are involved. To deal with these risks is all the more difficult in many developing countries. The ability of governments to overcome them, create new markets and strengthen institutions is then the crucial factor in technology development.

This is not to say that it is easy to mount effective policies. Many governments have failed to improve markets and stimulate technology development. On the contrary, their interventions are often themselves important causes of market failure. However, government failure is not inevitable. Where governments succeed in strengthening national learning systems, as in some Asian newly industrialized economies, they have triggered growth and technological success. The lesson is not that there is no role for policy, but that this role is difficult, and must support rather than displace markets. The design of policies must rely on an understanding of the technology development process, the role of TNCs in this process, and their interactions with local learning.

B. Technology generation and transfer: the role of TNCs

1. Technology generation

The preceding analysis has demonstrated that it is difficult to gauge innovative technological effort. The new technology paradigm conceptualizes innovation and knowledge as encompassing product and process technology as much as organization and tacit knowledge. The softer technology becomes, and the more it is embodied in people, the more difficult it becomes to measure the generation of technology and the role of particular groups of firms in it. Conventional measures, notably R&D spending or patents registered, are therefore becoming less indicative of technological accomplishments.[2]

To the extent that such data can nevertheless be used as indicative, they show that technology generation is concentrated in advanced industrial countries, and takes place mainly in large firms (which are typically TNCs). For example, R&D spending[3] – a proxy for the "input" of technological effort at the macroeconomic level – is concentrated in the OECD countries, with about 90 per cent of world R&D expenditure within this group; seven countries account for 90 per cent of R&D; the United States alone for 40 per cent.[4]

Innovative activity is also concentrated at the enterprise level. Using R&D spending as an indicator, a small number of firms dominate R&D in industrial countries (Mani, 1999). In the United States, for instance, just 50 firms (of a total of over 41,000) accounted for nearly half of industry-based R&D in 1996 (table VII.1). Among them, the identity of the leaders changed: one-third of the leading R&D performers in 1996 were newcomers to the list as compared to a decade earlier (annex table A.VII.1). In small developed countries, the level of concentration is even higher. In Switzerland, just three firms accounted for 81 per cent of national R&D in the early 1980s, and in the Netherlands, four for nearly 70 per cent (Kumar, 1998, p. 20).

Table VII.1. Leading United States R&D spenders, 1996

Number of firms	R&D (Million dollars)	Per cent of United States total
10	34 201	24.5
20	47 738	34.2
30	58 010	41.6
40	64 432	46.2
50	68 963	49.4
100	81 040	58.1
Total United States [a]	139 579	100

Source: UNCTAD, based on NSB, 1998a.

a Total industry funded, including federally financed R&D, covering more than 41,000 firms.

In all but a few industries, technological advantage is a powerful – often the most powerful – determinant of outward FDI (Dunning, 1993). Hence, most FDI emanates from the main innovating countries;[5] the firms dominating United States R&D, for instance, are almost all transnational (annex table A.VII.1). Moreover, most TNCs based in developed countries are large. Size confers an advantage in conducting risky, large-scale R&D. Increasingly, firms also need to amortize the rising cost of R&D across a larger number of markets, be it through equity or non-equity forms of involvement, which implies that these firms have an interest in open FDI regimes.[6] Transnationality in turn reinforces technological prowess, among other reasons because TNCs can tap more effectively sources of foreign technological knowledge and expertise.

TNCs are gaining overall in their role in technological effort. Scale economies in R&D and the need for a global presence to finance it and exploit its results dominate other influences. Large TNCs are at an advantage in forming alliances. Many successful small innovators go transnational to commercialize their innovations; in a globalizing world economy, in which competition is everywhere, they are increasingly forced to so do. Even where innovators subcontract production to other firms, breaking the traditional link between innovation and manufacturing, the importance of TNCs does not diminish. [7] The innovators remain large brand-named firms with large market shares and substantial transnational presence.

Nevertheless, there are many purely domestic firms that are leaders in innovation. Highly effective innovator firms can also be found among small and medium-sized enterprises (Audretsch, 1995). Also, firms from developing countries innovate, either on their own, in conjunction with supportive technology strategies offered by governments, or in different forms of alliances with TNCs. The advantage for these firms lies in the formative stages of new and emerging technologies, making customized industrial machinery, or designing fashion-sensitive consumer items – areas in which they may initially be exploiting niches that subsequently offer opportunities for further technological upgrading.

Do TNCs spread their innovative activities internationally? While R&D is subject to the same factors that are driving the globalization of other TNC activities and that make every part of the value-added chain potentially subject to FDI, there is less relocating of innovatory capacity abroad than observed for other functions. Not only are there large transaction, communication and coordination costs in locating R&D activities abroad, there are also strong synergies between corporate R&D and the science and production system around it. These external economies add to the inertia in setting up innovation abroad (Porter, 1990).

However, this is not necessarily true for all countries or all periods. Take patents registered by TNCs in the United States by their head offices and affiliates abroad as an indicator of the international spread of R&D.[8] One study shows extensive overseas patenting by TNCs even in the inter-war period (Cantwell, 1995). National tendencies differed. French, Swiss and German TNCs had relatively low shares (three to six per cent) of patents taken out by affiliates as compared to headquarters. At the other end, Belgian TNCs had 95 per cent of patents arising abroad. British, Italian and Swedish TNCs were in the middle (with 28-31 per cent) and United States TNCs were moderately low (seven per cent). In the period 1940-1968, affiliate patenting rose for most of Europe (from 12 to 27 per cent), but not the United States (it fell to four per cent). After 1970, foreign patent shares of United States TNCs rose steadily (table VII.2), exceeding those in the inter-war period by 1991. European countries continued to have generally higher ratios; the average declined till 1978 and rose consistently since. Japanese firms continued to keep most innovation at home.

While international innovative activity by TNCs is of long standing, differences are emerging in the new context. There is now a greater spread of firms conducting R&D outside their home countries. This is partly a reflection of their growing production overseas; previously, affiliates had conducted overseas R&D mainly to exploit parent company strengths in local markets by providing support for production and adaptation. But the relocation of some R&D activity is more characteristically a response to the changing nature of innovation: along with necessary technical support, firms are increasingly integrating their innovative activities throughout their TNC systems, with affiliates specializing in line with their capabilities. This is the "new globalization of technological innovation" (Cantwell, 1995, p. 168). An analysis of leading TNCs with high levels of affiliate patenting throws further light on the nature of their R&D activity (box VII.2). It suggests that adaptation and technical support are still the main

Table VII.2 . Share of United States patents registered by the world's largest firms attributable to research in foreign locations, 1969-1995

(Percentage)

Nationality of parent firm	1969-1972	1973-1977	1978-1982	1983-1986	1987-1990	1991-1995
United States	5.0	5.9	6.4	7.5	7.9	8.6
Germany	12.8	11.1	12.1	14.5	17.1	20.7
United Kingdom	43.1	41.2	40.5	47.1	50.4	55.8
Italy	13.4	16.0	13.9	12.6	11.1	16.5
France	8.2	7.7	7.2	9.2	18.2	33.2
Japan	2.6	1.9	1.2	1.3	0.9	1.1
Netherlands	50.4	47.4	47.7	54.0	54.0	55.7
Belgium-Luxembourg	50.4	51.1	49.3	58.2	47.5	53.3
Switzerland	44.4	43.6	43.8	41.6	43	52.5
Sweden	17.8	19.9	26.2	28.9	30.6	42.4
Austria [a]	5.1	16.8	19.8	11.8	8.0	-
Norway [a]	20.0	1.7	12.3	32.5	37.1	20.2
Finland [a]	18.9	27.1	26.9	18.7	27.9	39.5
Canada	41.2	39.3	39.5	35.8	40.1	44.0
Others	28.2	22.2	26.4	30.3	7.5	3.9
Total	10.0	10.5	10.5	11.0	11.3	11.3
Total excluding Japan	10.5	11.6	12.3	13.9	15.8	16.5
Total European countries [b]	28.0	25.2	24.5	27.0	30.0	34.8

Source: Cantwell and Janne, 1998.

a Patents less than 50 for several periods.

b Austria, Belgium-Luxembourg, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

motive for affiliate R&D, but that there is an increasing trend towards tapping into foreign centres of innovative excellence. The changing strategies of TNCs are leading to more “asset seeking” overseas investment (UNCTAD, 1998a).

Box VII.2. Technological activity by foreign affiliates in developed countries

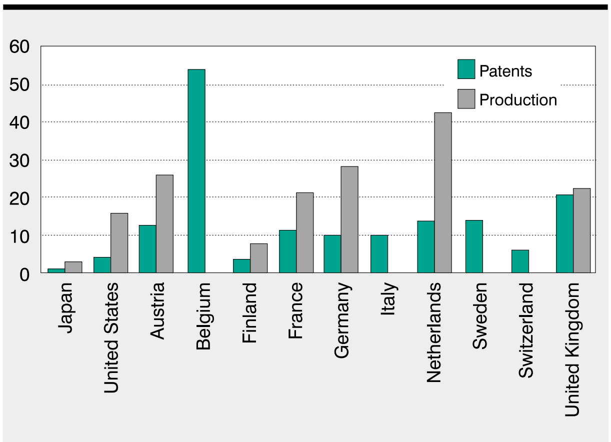
The following findings are based on a study of 220 leading TNCs with the highest volumes of affiliate patenting in the United States. These TNCs account for 30 per cent of all patenting during 1990-96, and around 20 per cent of their patenting comes from affiliates abroad. Of the 220 firms, 71 are North American, 127 European and 22 Japanese.

- The most important location for overseas R&D is the United States (41 per cent), followed by Germany (17 per cent) and the United Kingdom (12 per cent). Japan is the least important of major OECD countries (five per cent).
- Less than one per cent of overseas patenting arises from outside the Triad (North America, European Union and Japan).
- In over three-quarters of the cases, TNCs locate their technology abroad in core fields where they are strong at home. The advantages of physical agglomeration of R&D activities and close linkages with the national science base are overwhelming for launching most major innovations.
- In 10 per cent of the cases, TNCs establish technological activities abroad to exploit the technological advantage of the host country. This is increasing where the domestic science base cannot provide the relevant skills and knowledge in relevant fields with equal effectiveness, a particular problem for small countries. TNCs from small countries like the Netherlands, Sweden and Switzerland increasingly establish foreign R&D to develop families of products in a specific field for world markets. However, TNCs even from large countries like the United States, United Kingdom, Germany and Japan set up overseas R&D units to exploit science bases with different areas of competence.
- The largest increases in overseas technological activity occur when the domestic strengths of the company complement those of the host country.
- The degree of internationalization of R&D is not positively associated with the overall research intensity of the industry. On the contrary, it tends to decline with technology intensity, with the major exception of pharmaceuticals. In aerospace and electronics, for instance, around 90 per cent of patents arise from the parent company.
- Adapting products and processes to foreign conditions and providing technical support remain the main reasons for overseas R&D units. However, there is increasing technological activity to tap into developments in foreign centres of technological excellence. National science systems increasingly involve linkages between local science institutions and foreign affiliates.

Sources: Patel and Vega, 1997; Patel and Pavitt, 1998.

Countries with high proportions of patents taken out abroad also have high shares held by large foreign firms in their national patents – they are technologically more “internationalized” in both senses (figure VII.2). A number of European countries are more international than the United States and especially Japan. Smaller countries are more international than large ones, though the United Kingdom is an exception in being relatively large as well as highly internationalized. Interestingly, the shares of foreign firms in production are invariably higher than their shares in patents – foreign investors have, by this measure, lower innovation intensity than local firms (Patel and Pavitt, 1998).

Figure VII.2. Shares of large foreign firms in national patents and production, 1992-1996



Source: NSB, 1998.

Transnational R&D is clearly globalizing, following, if slowly, the globalization and integration of other TNC functions. Internal transaction and coordination costs are falling as TNCs set up new communication and organizational systems. The growth of international production is leading to more overseas (adaptive and supportive) R&D effort. So is the growth of M&As when acquired firms possess R&D facilities. These facilities have to be restructured and integrated into the TNCs' technology system. This may involve upgrading, downgrading, or closure (and sometimes asset stripping), depending on corporate strategy and local capabilities (box VII.3). Whatever the mode of setting up or acquiring overseas research facilities, the main determinant of innovative (as opposed to adaptive) R&D is local innovative capability. Competition and technical change are forcing TNCs from all countries, large and small, to search for and utilize sources of information and research excellence (Pietrobelli and Samper, 1997). National innovation systems are increasingly unable to provide the entire range of support needed.

Nevertheless, given the continued significance of local innovation systems, practically all affiliate innovative R&D goes to other industrial countries. Developing countries attract only marginal portions of TNC affiliate research, and much of what they get relates to production (adaptation and technical support) rather than innovation. Nevertheless, in recent yeas, TNCs have been locating some of their strategic R&D in a number of developing countries that have built up the required innovative environment (Reddy, 1997). This is discussed at greater length below.

Box VII.3. Downgrading of local innovatory capacity: examples from Brazil

The take-over of a local firm by a transnational one can have detrimental effects on the innovation capacity in the enterprises concerned. Several experiences in Brazil illustrate this. For example, in 1996 and 1997, a number of TNCs acquired several large domestic auto parts producers - Metal Leve, Freios Varga and Cofap. Subsequently, the R&D activities of the local firms were downgraded, and their frontier research was relocated to the parent firms' R&D centres in their home countries.

Even in high-technology firms, R&D activities were scaled down when TNCs bought into them. This was the case, for example, when in 1992 Alcatel purchased Elebra Multitel, one of the most important producers of switching systems. In 1999, Zetax and Batik, two domestic firms producing and continuously upgrading a technologically-advanced switching system, Trópico, became part of Lucent Technologies. Interviews indicated that Lucent was not interested in local R&D, prefering to rely on technologies developed in the parent company. A similar process has been observed in other telecommunications foreign affiliates in Brazil. Since they are increasingly exposed to international competition, they are scaling down local R&D, and centralizing it in parent firms, as a cost-reducing strategy. In particular, R&D activities geared to the development of new products was discontinued in a number of cases, and effort shifted into the more simple adaptation of imported processes and products. In most cases, this has meant that highly-qualified engineers engaged in R&D are transferred to other, less-specialized functions, such as production, quality assurance, sales or marketing. Some estimates suggest that local R&D expenditure in the telecommunications industry may have dropped by as much as 50 per cent during the 1990s.

A related development observed in the hi-technology telecommunications and information technology clusters in Campinas and São Carlos is that the newly- established affiliates are not linking into locally-based supplier networks. Instead, they operate in isolation from the domestic innovation system, relating to their parent companies and other affiliates rather than to local firms. This too has a negative impact on local R&D capacity, since spillover effects from networking and learning processes are diminished.

As a result, the country is losing the competitive edge it had developed in some product markets. This reinforces a process of increasing import intensity that began with trade liberalization in the early 1990s. For example, the import penetration coefficient for parts and components in the automobile industry increased from eight per cent in 1993 to 20 - 25 per cent in 1996; import penetration in information technology and telecommunications products soared from 29 per cent in 1993 to around 70 per cent in 1996 (Laplane, Suzigan, and Sarti, 1998). If local production of high-technology intermediate inputs in production continues to decrease, the share of imports is bound to intensify further. The impact on technology would then be reinforced by a problematic impact on the trade balance.

Sources: Cassiolato and Lastres, 1997, 1999a and 1999b.

2. Technology transfer

Technology transfer involves the transfer of physical goods (e.g. capital goods) and the transfer of tacit knowledge. The latter is becoming more important and involves acquiring new skills and technical and organizational capabilities. Further technical adaptations are needed as the technology is implemented. The costs can be substantial. According to one study (Teece, 1976), transfer costs can comprise between 20 to 60 per cent of total project cost. The costs of transfer rise with "technological distance" or differences in technological specialization, corporate tradition, skill levels and the like. This distance also varies within similar countries, leading to different transfer costs. When countries have very different levels of technological capabilities, the costs of transfer are much larger.

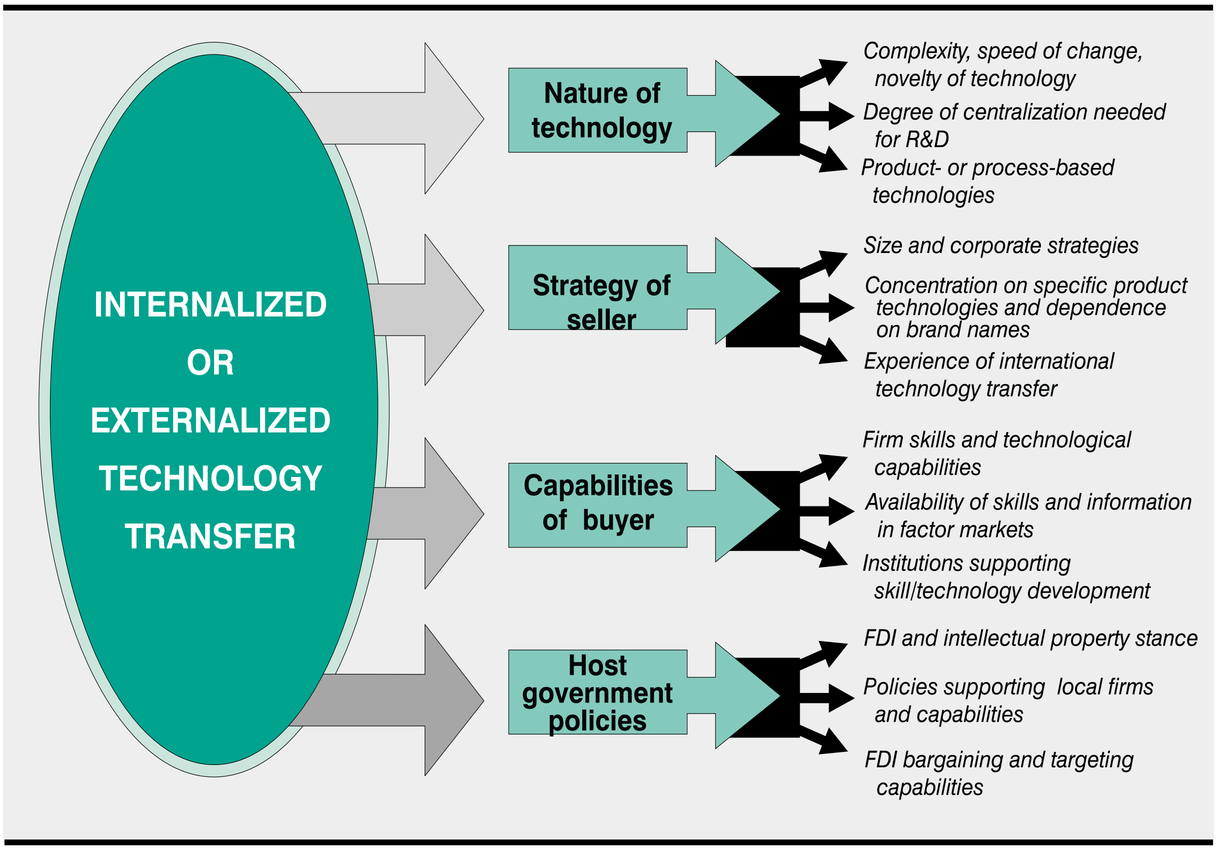
Unlike physical goods, it is not easy to define the technology "product". The market is fragmented and ill-defined. A product can take many different forms, depending on how much information sellers include (or the buyers ask for) and how they transmit or teach this information. The seller of technology always knows more about the product than does the buyer – it would otherwise have nothing to sell (Arrow, 1962): the buyer operates under a basic information asymmetry. Even with full information, the parties can put genuinely different valuations on technology, depending on their market positions, expectations and technological capabilities. For these reasons, the price of technology is subject to bargaining. This sale itself can take many different forms, with varying commitments to the transfer of knowledge and skills over time.

The benefits of technology transfer are also difficult to measure. In the short term, the immediate recipients benefit by having higher productivity, new products and / or lower costs. Over the longer term, however, their benefits depend on how much they learn from the technology and are able to deepen and develop their own capabilities. For an economy as a whole, the benefits also include the diffusion of the technology and its spillovers to other firms and institutions. In an activity that is so prone to unpredictable dynamic learning effects and has so many externalities, the net outcome is very difficult to assess (Pack and Saggi, 1997). Short-term and long-term effects differ, and private benefits can diverge from social ones. These problems are particularly important in developing countries.

TNCs transfer technologies in two ways: *internalized* to affiliates under their ownership and control, and *externalized* to other firms. *Internalized* transfer takes the form of direct investment and is, by definition, the preserve of TNCs. It is difficult to measure and compare directly the amounts of technology transferred in this manner. Measured by payments for royalties and licence fees, a substantial part of the payments is made intra-firm (annex tables A.I.3 and A.I.4). As rising costs are forcing firms into more technology-based alliances, internalization – understood in a broader sense – can also be seen to encompass technology transfers among clusters of innovative TNCs. The increase of such alliances and networks has led to a blurring of the distinction between externalized and internalized modes of technology transfer. Policy liberalization by host governments also tends to favour internalization strategies.

Externalized modes of transfer by TNCs take a variety of forms: minority joint ventures, franchising, capital goods sales, licences, technical assistance, subcontracting or original equipment-manufacturing arrangements. TNCs are not the only source of externalized technology, of course. But they are very important in high-technology activities and in providing entire "packages", i.e. technology together with management, marketing and so on. Where only discrete elements are involved, such as process plants or specific items of technical knowledge, specialized engineering and consultants firms play a more important role. Similarly, in activities with stable or simple technologies, where technology is highly embodied as in capital goods or where TNCs do not have strong ownership advantages, technologies can be acquired at arm's length.

Figure VII.3. Determinants of the mode of technology transfer



Source: UNCTAD, 1995b, p. 23.

The international technology scene is so dynamic that it is difficult to generalize about trends. While the rising costs and risks of R&D in some technologies are leading to greater concentration (Ernst and O'Connor, 1989), there is more fragmentation and competition in other technology markets. It is not clear, therefore, whether on balance it is easier or more difficult to obtain technology at arm's length. Within advanced technologies, older vintages are easily available from innovators and imitators. In low-technology activities, new suppliers of technology and technical services are appearing, many from newly industrialized economies. TNCs often spin off independent companies to sell specialized engineering or consultancy services. International engineering and consulting companies set up affiliates or joint ventures in developing countries. For developing countries, the bulk of whose needs are in mature, standardized activities, technologies may well be available from more sources and on potentially better terms than ever before. For newly industrialized economies that need advanced technologies, on the other hand, externalized purchases may be more difficult than before in some product segments. In other cases, the intensity of competition among suppliers, and the fact that product cycles are becoming ever shorter, are opening up access to the latest technologies via external acquisition, albeit at high prices. This appears to be the case in the electronics industry.

What determines the mode of transfer? Several economic, strategic and policy factors are involved (figure VII.3). The nature and speed of change of technology, transfer costs and risks, corporate perceptions of benefits and risks and government policies all play a role (Pietrobelli and Samper, 1997). Corporate strategies and host government policies aside, internalized transfers are preferred by firms the more complex and fast moving the technology, the larger, more transnational and more specialized the supplier, and the less developed the capabilities of the buyer. Externalized transfers are preferred the more stable and simple the technology, and the smaller, less internationally experienced and more technologically diversified the sellers.

The profitability of a technology to a firm depends on its novelty, commercial value and complementarity to existing technologies, relevance to the firm's core competencies and area of business and pressure from imitators. TNCs – like uni-national firms – do not generally sell their most profitable technologies to unrelated firms abroad as long as there are other means of exploiting them, though they use them increasingly in technology alliances when they expect greater technological rewards. They are willing to sell more mature technologies, as long as the buyer does not pose a competitive threat. Where they perceive such a threat, they might sell the technology but hem in its use by restrictive clauses on exporting or further development. TNCs often manage externalized transfers to keep buyers from accessing the core elements of a technology. A competent technology buyer may therefore find that it becomes progressively more difficult and expensive – and finally impossible – to obtain new, commercially successful technologies at arm's length. A great deal of R&D goes into getting around this problem: all good follower strategies involve considerable technological effort to keep up with innovators.

Finally, consider the *content of technology transfer* by TNCs. An important feature of internalized transfers is that a TNC can transfer technology to different affiliates at very different levels. The choice depends on two factors: corporate strategy and affiliate capabilities. *Corporate strategy* defines the role assigned to each affiliate within the transnational production system of the parent firm. It reflects the balance between location costs and risks, market size and growth expectations, and competitors' behaviour. It can also reflect the strategies of affiliates. For instance, an affiliate can (if it has the necessary capabilities) bargain with the parent firm to increase its technological role. One strategy is for an affiliate to get a "product mandate". Product mandating involves an affiliate taking global responsibility for developing, producing and marketing a product. This gives it a greater innovation role than, say, producing the entire product range in a miniature version of the parent firm. For instance, the Canadian affiliate of a United States automotive TNC received a mandate to both develop and manufacture one particular vehicle. By reducing its range of assembled vehicles to concentrate on this model, it was able to deepen its design and development capabilities and build up local suppliers and skills. The growth of deep integration by TNCs reflects the increasing use of such mandating strategies, with greater specialization by both headquarters and selected affiliates in particular functions (UNCTAD, 1993a).

The second determinant, of particular importance to development, is the *technological capability of the affiliate*. In making transfers to an affiliate, a TNC can choose between a range of technologies of different vintages and levels of complexity. Each technology can comprise processes of varying levels of complexity, from simple assembly at one end to R&D at the other. The choice of technology or function reflects costs and benefits to the company as a whole. The ability of an affiliate to deploy technology efficiently is a major element: the lower the capability, the lower the appropriate content of the transfer. A simple example illustrates this (box VII.4) and explains why transfers to affiliates in developing countries typically have lower technology content than in advanced or newly industrializing ones. It also shows why globalization may result in growing inequality in TNC technology transfers between countries. Since each affiliate increasingly has to compete in world markets, host countries with low capabilities and weak learning systems may be left progressively behind those with dynamic capabilities.

Box VII.4. Differing technology content in TNC transfers

Imagine a developed country TNC transferring technology to its affiliates in different host countries (box figure VII.4). To simplify, assume all host countries have similar FDI regimes and locations. The spread of R&D among affiliates may be characterized as follows:

- Affiliate 1 is in another developed economy, a large operation serving the regional market. It performs the full range of technological, managerial and marketing functions, sharing some on a specialized basis with the parent "deep integration" (UNCTAD, 1993). It is in a country with a strong research tradition in its area. The affiliate has R&D facilities at full parity with the parent firms and interacts with local universities, institutions and firms. There is free flow of technical personnel and information both ways. Technologies can be developed and launched in either

/...

(Box VII.4, concluded)

location or in both simultaneously. This is the highest level of transfer: equality in capabilities and full information sharing.

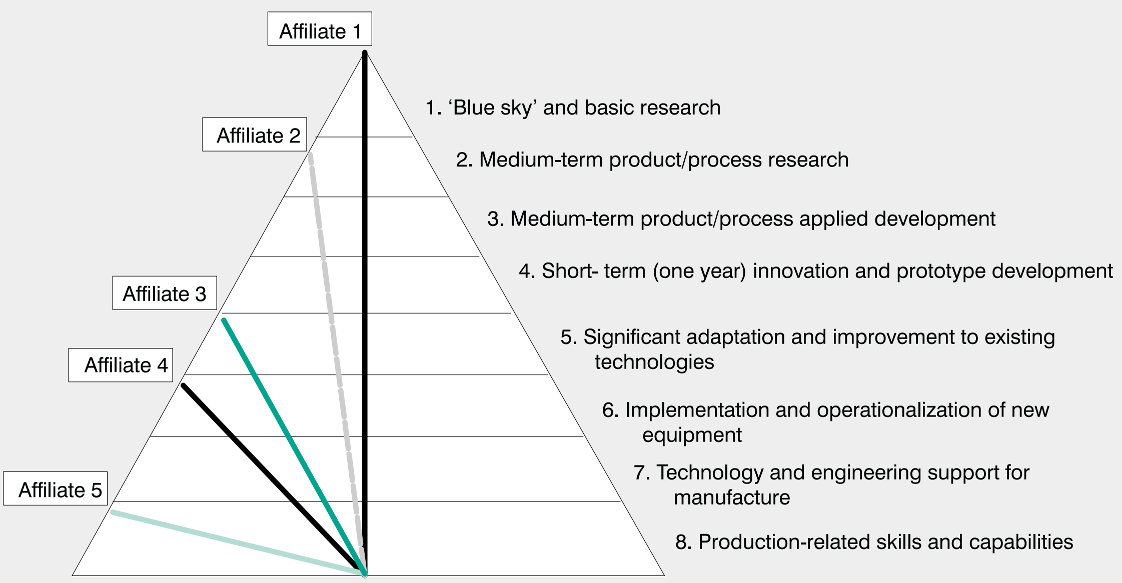
- Affiliate 2 is in a newly industrializing economy, with state-of-the-art manufacturing facilities to serve local and regional markets. It has an R&D facility for certain design and development functions; this interacts with some local firms, technical institutes and universities. There is strong local content in production, management, marketing and engineering, but many head-office strategic functions are not shared with the affiliate. The relevant technical information flows freely between the affiliate and the parent firm, but the level of sophistication is lower than with the first affiliate.

- Affiliate 3, in a less industrialized, export-oriented economy, is in an export-processing zone assembling kits made by affiliate 2 for regional export markets. Local content is low, mainly packaging and printing. A significant part of top management and technical staff are expatriates. Technology transfer is mainly embodied in capital goods and training for assembly and quality management. There is practically no interaction with local firms or institutions.

- Affiliate 4 is in a protected economy with a large, but technically stagnant, industrial base. It is obliged to have high local content, so interacts closely with local suppliers. It uses older vintages of technology to sell less sophisticated products on the local market, and makes little effort to match its cost and quality to world standards. It does make some effort to adapt its materials and products to local conditions (the figure does not capture the lag in its technical efficiency).

- Affiliate 5 in a least developed country, is a small assembly operation aimed at local markets. Demand is small, the skill base is low, and there are no significant local suppliers or technical institutes. The plant is tiny, doing "final touch" assembly, with only basic quality control and maintenance. There is practically no adaptation or process engineering. Technology transfer consists of a few weeks of training to local shop-floor and supervisory staff; its technology content is minimal.

Box figure VII.4. Content of technology transfer



Source: based on Hobday, 1996.

Source: UNCTAD.

The relationship is not just one way, from capabilities to content. It is organic and interactive. The growth and depth of local capabilities depend critically on access to new technologies and on the learning required to master them. Higher technological content poses greater challenges and generally offers greater learning potential. The ideal virtuous circle is one where a host country raises its absorptive capacities and imports technologies to "stretch" its learning processes; the least desirable situation is one in which initial capabilities are low and technology imports fail to stimulate further learning. The first leads to dynamic growth, the second to technological stagnation. Similar sequences apply to externalized technology transfers. However, here the buyer of the technology plays a larger role in deciding technology content. It is possible for a dynamic local firm, in a supportive learning environment, to push out its technological frontier quicker than an affiliate without conflicting with a TNC's global strategies. It is also possible, however, for a weak local firm to remain at the bottom of the technological learning ladder. This can be worse for the country than internalized transfer, since operational efficiency can be lower without the support of a foreign parent firm.

C. FDI and developing countries: technology transfer, diffusion and generation

1. Technology transfer

TNCs are among the main sources of new technology to developing countries. As noted, they provide technology in many forms, and there are several sources of externalized technology transfers. The benefits and costs of internalized FDI technology transfer must be judged with reference to the alternative of externalized transfers – the ultimate source of both may be TNCs.

Let us start with the *advantages* of internalized transfers. FDI provides financial resources in addition to technology. Even if FDI crowds out local investment, it might enable the host economy to expand its productive base and so use a larger range of technologies. Moreover, many technologies are available only in internalized forms. These are generally new, valuable technologies (based on expensive R&D integral to branded products) that firms are unwilling to sell to unrelated parties. They may also be mature technologies used in processes integrated across several countries, as for assembly of semiconductors for export. For countries that are part of export-oriented operations, internalized transfer is very important to obtain mature as well as latest technology, depending on the product or market concerned.

Even when technologies are available in externalized forms, internalized transfers are often cheaper and quicker. Where the technology involved is very large-scale, foreign investors are often able to mobilize the resources needed more efficiently than local firms. Where the buyer is likely to become a competitive threat, technology sellers charge high prices for new technologies, provide only older vintages or impose conditions to protect their markets. Such restrictive business practices (e.g. export restrictions, prohibition of sub-licensing, ban on local improvements) have an economic rationale, but they raise the cost of externalized relative to internalized modes. Where technologies change rapidly, repeated contracting may be cumbersome and slow, leading to high costs or technological lags. Internalized modes allow affiliates to have access to technologies generated by their parent firms. However, the extent to which foreign affiliates actually have access to them depends on the parent firms' strategy and the affiliates' capabilities. In general, foreign affiliates tend to be in the forefront of introducing new management and organizational techniques, quality management standards, training methods and marketing methods. One of their most immediate responses to liberalization in host countries has been to improve these elements of affiliate operations (box VII.5).

The most important benefit of internalization, however, is that it provides, at least in principle, access to the whole range of TNC technological, organizational and skill assets, including its tacit knowledge. Direct comparisons of costs of internal and external transfers tend to assume that affiliates and local firms deploy technology with equal efficiency. While this may be true of some affiliates and in some developing countries, it is not of many others. Where the technology transferred is superior to that of local capabilities, the efficacy of the

Box VII.5. TNCs and the restructuring of Argentine industry

Liberalization together with price stabilization and the rapid growth of the domestic economy have been decisive factors to attract significant FDI inflows into Argentina in the 1990s. The privatization of public enterprises and the automotive and mining regimes has also induced many TNCs to invest in the country. This has brought significant changes to both service and manufacturing activities, but the impact has been uneven. A survey of foreign firms shows the following:

- *Productivity and quality*. TNCs took over several state-owned service utilities and made significant changes. They laid off excess staff, and changed procurement and subcontracting policies to reduce costs and delivery times. Utilities firms improved their client records and collection methods. As a result, labour productivity and, in some cases quality standards, rose. In the telephone companies, for example, the number of lines in service per employee increased sharply. Quality indicators, such as uncleared errors, average repair time and percentage of lines out of service, improved. New services were offered to customers. Even so, there were large gaps in productivity, telephone density and quality indicators *vis à vis* the parent companies, and service charges remained higher. There were also quality improvements in other privatized services, though more modest than with telephones: the gas and electricity regulatory bodies fined foreign operators for non-compliance with targeted quality standards. In manufacturing, most enterprises have rationalized costs and raised efficiency to cope with trade liberalization, helped by growing internal demand. In automobiles, productivity increased from 5.7 to 14.9 vehicles per employee and the time needed to make a vehicle fell by 38 per cent between 1990 and 1993. However, despite these improvements, productivity levels in Argentina were still well below international levels, and quality problems were aggravated by the rapid and large increases in output. The use of new manufacturing techniques was uneven, with new entrants more active in adopting them. Established firms, with large sunk equipment costs, Fordist mass-production traditions, an uneven upgrading of suppliers and worker resistance, were less progressive. While the new policy regime imposed lower local content requirements, automobile TNCs sought to develop local suppliers to comply with sectoral foreign trade targets and reduce high levels of vertical integration. They provided technical assistance to local component suppliers, encouraging joint ventures with Brazilian enterprises to reap economies of specialization and modernization. The existence of a sectoral bilateral trade agreement with Brazil has encouraged TNC affiliates in Argentina and Brazil to specialize in order to reap benefits from scale economies by trading finished vehicles and parts between both countries.

- *Management and organizational techniques*. TNCs made significant management changes, laying off excess staff, and introducing new management methods and computerization. In telecommunications, where technologies change rapidly, TNCs diffused the latest technologies, mainly via skilled personnel. In other privatized services like gas, power or water, with slow technological change, the contribution of TNCs was in the design of investment plans, automation and efficiency improvements. In electricity and gas, TNCs hived off business operations and services previously carried out internally by state enterprises. Most quality improvements were laid down in the privatization scheme and monitored by regulatory bodies; thus, it is difficult to separate the effect of regulation from that of foreign ownership *per se*.

- *Personnel training*. To remedy problems of deteriorating labour quality, manufacturing TNCs invested substantial resources in employee training in some cases up to one per cent of turnover, particularly in automobiles, auto parts and telecommunication equipment firms. The automobile firms, which had already set up technical schools, launched new training programmes jointly with the Ministry of Labour. Again, new entrants invested more heavily in training than established firms. In privatized state enterprises, training was used as a way of dealing with problems of redundant personnel, corruption, uneven technical skills and bad working habits. The share of technicians and professionals in total employment was also raised, particularly in telecommunications. Foreign personnel were placed in some key management positions, but local personnel filled other high managerial and technical positions.

- *Research and development*. In contrast to productivity and quality, TNCs gave little attention to promoting R&D in affiliates. Of the privatized utilities, only one telephone company had an R&D unit. This unit dealt only with domestic operations, with no link with parent company R&D. In manufacturing, the strongest R&D effort was in telecommunication equipment manufacturers. In one case, it reached one per cent of sales. These efforts concentrated on product development for market niches such as low capacity switches, certain electronic components and specialized software. One firm was able to license its developments to the parent firm and generate some exports. In food processing, two export-oriented firms were more active in R& D than the others, but their efforts were very modest. In automobiles, the main technological activity, using relatively small R&D teams, was to adapt products from the parent companies to local conditions.

Source: Chudnovsky, López and Porta, 1997.

transfer depends on how local firms and affiliates cope with the learning process. Affiliates can have lower learning costs and shorter learning periods because they draw upon the resources of their parent firms for the skills, information, experience, tacit knowledge pool and finance needed to absorb and adapt the technology. Foreign affiliates, in other words, may face lower market failures in technological learning in a new environment than local counterparts. They may charge affiliates for services provided, but the marginal costs are likely to be low in relation to a local firm that has to create the skills, knowledge and structures from scratch.

Apart from technological learning, internalized transfers can provide other benefits. TNC marketing skills and brand names make it easier to commercialize new technologies within the host economy or abroad. If a transfer is part of an export-oriented operation, the affiliate gains access to regional or global markets, or to an integrated international production network of the parent company (chapter VIII). Internalized transfers can also lead to similar transfers by other TNCs in vertically linked activities. For instance, export-oriented TNCs in such countries as Malaysia attracted their suppliers to invest locally and so deepen the production process.

What are the *disadvantages* of internalized transfers? In internalized transfers, the host economy pays not just for the technology but for the whole package brought by a TNC, including its brand names, finance, skills and management. Where local firms possess the capability to use the technologies efficiently and do not need these other assets, internalization can be more expensive than externalization (assuming the technology is available at arm's length). The benefits of unpackaging FDI have been discussed for a long time (e.g. Rosenberg 1976; Rosenberg and Frischtak, 1985), but they are not accessible to all host countries. Whether or not countries can "unpackage" FDI efficiently depends on the nature of the technology and domestic capabilities. For technologies readily available on licence, and in countries with relatively well-developed entrepreneurial and technological capabilities, externalized modes are indeed likely to be cheaper. In other cases, they are likely to be more costly, inefficient or simply not feasible.

From a development perspective, the largest drawback of internalized modes lies in the control by TNCs of their "ownership advantages". While their efficient internal markets for skills and knowledge make it easy to use new technologies inside their corporate systems, this process can hold back deeper learning processes and spillovers in the host economy. There is likely to be less effort to absorb, adapt, improve or innovate technology in affiliates than would be the case when local companies buy a license or equipment in the externalized mode of technology transfers, and build upon the acquired technology (know-why). In the short term, an affiliate may be more efficient in *implementing* a given technology (i.e. it gets operational know-how more quickly). In the long term, however, it may develop fewer innovation capabilities than a local counterpart. In the restructuring process in response to liberalization, affiliates may neglect the development of R&D capabilities (box VII.5).

Some of the economies that succeeded most in building up domestic technological capabilities - the Republic of Korea and Taiwan Province of China for example - did so by relying mainly on externalized technology transfer. Nevertheless, local firms often had long-term relations with TNCs in the form of subcontracting or original equipment manufacture contracts. They also encouraged the absorption of imported technologies in a strongly export-oriented setting, thus forcing local firms to develop and deepen their own technological capabilities (Lall, 1995; Ernst, Ganiatsos and Mytelka, 1998a). As firms became internationally competitive and needed more sophisticated products, they found that externalized transfers were insufficient. The latest vintages of technology were often simply not available from the innovators – they had to import technology either by going into other arrangements (franchising or original equipment manufacture) and / or by investing in their own R&D to imitate and build upon foreign technologies. Some firms became outward investors to engage in alliances with, or take over, innovative firms abroad or to establish listening posts in industrial countries. The process of restricting inward FDI while encouraging local capabilities to absorb TNC technologies required the rapid build-up of strong R&D capabilities. In the Republic of Korea, for example, R&D capabilities were developed in the large *chaebol* fostered by the government; in Taiwan Province of China, largely populated by smaller firms, the authorities themselves also played a role in R&D.

Internalized transfers by TNCs reflect the strategy of the parent company and its assessment of what is appropriate to local capabilities. This assessment depends on current skills and capabilities: a rational investor exploits *existing* comparative advantages, and attempts to create dynamic comparative advantages. Thus, a TNC would place its simplest assembly technologies in an industrially backward economy, providing the training and information necessary to operate such technologies. Over time, as wages rise, it may automate the technology (as with electronics TNCs in Malaysia) (Rasiah, 1994); or, as skill levels rise, it may upgrade the technological functions served. On the other hand, where sunk costs are low, the TNC may close down operations as wages rise and set up in a lower wage country. In more advanced countries also, a TNC may decide to shift high-level technological functions to take advantage of local capabilities, or downgrade technological functions as part of a larger global strategy.

What is rational for a TNC can be undesirable for host country development if private and social interests diverge because of costly, uncertain learning processes and deficiencies in factor markets. TNCs may not be willing to upgrade affiliate technological content as fast as host governments think desirable to stimulate local industrial deepening. If local firms are able to move more quickly up the learning ladder, externalized transfers may be more desirable. The case is similar to that for protecting infant industries, based on temporary measures to overcome costs of learning.

There are important *qualifications* to these arguments. It is assumed that local firms have the capabilities to undertake efficient learning with externalized transfers. Externalized transfers may not lead to technological deepening if local firms do not or cannot invest sufficiently in the learning process. In many countries, the promotion of licensing to local firms has not led to technological competence. On the contrary, in many import substitution regimes it has fostered technical lags and inefficiency. In India, for instance, many local firms remained technologically dependent on foreign technology and failed to develop internationally competitive capabilities over decades of such a policy. The problem was exacerbated when governments promoted local firms without simultaneously improving the skill or institutional base. Without the right competitive incentives, firms do not invest in their capabilities; without efficient factor market and institutional support, they cannot go very far. The newly industrialized economies that successfully promoted domestic capabilities had an integrated strategy, building the educational base and strengthening technology institutions along with protecting their learning processes, while forcing firms into export markets as a mechanism to test and advance their competitiveness.

Governments can induce TNCs to improve the content of their technology transfer by providing better domestic skills, capabilities, supplier networks and infrastructure. Some countries have stimulated technological upgrading in affiliates by investing in the supply side of their capabilities and offering incentives to TNCs for the transfer of more advanced technical functions. The best example of this strategy is Singapore, which leads the newly industrialized economies in FDI targeting and promotion. What is not clear, however, is how this approach to upgrading would perform in comparison with an alternative strategy of promoting local firms directly, and under which circumstances either approach would lead to greater depth of capabilities.

2. Technology dissemination and spillovers

The use of new technology by the recipient is only one of its benefits. Another, often larger, benefit is the diffusion of technology and skills within the host economy. Many forms of diffusion are not priced or paid for in markets. They are externalities that arise involuntarily or are deliberately undertaken to overcome information problems. These effects fall under three headings: *linked economic agents, other firms and institutions* and *competing firms.*

a. Linked economic agents

Firms diffuse technology and skills to suppliers, customers and institutions with which they have direct dealings. Most industries have dense vertical networks of information exchange and cooperation to facilitate production, planning and technology development. In fact, many would cease to function if such extra-market linkages did not exist – pure markets, with anonymous price-based transactions, could not provide the information and coordination needed. Learning and innovation also tend to be greater in clusters where networking is high (Porter, 1990; Nadvi and Schmitz, 1994; Porter, 1998; Ernst, 1999). In the current technological revolution, networks and synergies are assuming even greater importance (Best, 1990; Archibugi and Michie, 1997; UNCTAD, 1998d). Firms outsource components and services more than ever. They collaborate more closely with suppliers and buyers in their technological efforts. Globalization gives such collaboration an international dimension: supply contracts extend over national boundaries, suppliers follow their customers overseas, new suppliers are located in cheaper areas, and so on (box VII.6).

How intense are the linkages that TNCs establish in developing host countries? How do these compare with linkages by domestic firms? Let us consider the most obvious manifestation of linkages, *sourcing*: the purchase of inputs, components and services from local as opposed to foreign suppliers. In an open economy, sourcing decisions of foreign (and comparable local) firms depend only on relative cost, quality and delivery, and reliable information on supplier capabilities. All other things being equal, firms prefer local procurement because proximity lowers transaction costs, allows for closer monitoring and gives greater flexibility in changing

Box VII.6. Promoting TNC technology spillovers in Taiwan Province of China and Singapore

When the Singer Sewing Machine Company started operations in Taiwan Province of China in 1964, there were several small sewing machine manufacturers in the country, with poor technology and no standardization, unable to compete in world markets. The authorities stipulated that Singer procure 83 per cent of parts and components locally within a year, provide local suppliers with standardized blueprints, send technical experts to improve productivity, prepare materials specifications and inspect final products. Singer was to provide local sewing machine producers with its own locally made parts at no more than 15 per cent above the price of parts imported from Singer's foreign parts. The company was also required to raise exports rapidly.

The company fulfilled all these requirements. It sent several technical and management experts to train and upgrade local suppliers and organize the entire production system. It provided a wide range of technical assistance to competing local sewing machine manufacturers free of charge. Suppliers received standardized blueprints enabling them to work to common specifications, measuring instruments and access to Singer's tool room and technical advice. Classes were conducted for suppliers in technical and management problems.

The result of the local content policy was a significant transfer of technology, increased backward linkages and upgrading of competitive capabilities for the industry as a whole. Within three years, Singer was using only local parts (except for some needles), and by 1986 was exporting 86 per cent of its total output. Other local firms also became major exporters, as local parts were standardized and improved in quality. One reason for this success was that relatively little investment was entailed. The existing base of technological capabilities in the local suppliers made the transfer and upgrading of technology relatively rapid and low-cost. This pattern was repeated over time in several other industries.

In Singapore, the Economic Development Board, the main industrial strategy-making agency, launched a programme to encourage subcontracting to local firms through its Local Industries Upgrading Programme. TNCs were encouraged to source components locally by adopting particular SMEs as subcontractors. In return for a commitment by TNCs to provide on-the-job training and technical assistance to subcontractors, the Government provided a package of assistance to the latter. TNCs were required to assign a full-time procurement officer to this programme, with his salary paid in full by the Government. SMEs received cost sharing grants and loans for the purchase of equipment, consultancy and training. By end-1990, 27 TNCs and 116 SMEs had joined this programme.

Sources: Dahlman and Sananikone, 1990; and Lall, 1996.

specifications and developing new inputs. Firms often place a great premium on face-to-face contacts with suppliers. The building of trust through direct interaction becomes more significant where tight technical specifications and quality are very important. For these reasons, as long as the costs of doing so are lower than resulting savings, firms invest in helping local suppliers upgrade their technology. In India, for example, truck manufacturers made extensive efforts to help actual and prospective suppliers to set up facilities, raise technological and skill levels, obtain inputs and find other customers (Lall, 1980).

All this is common to foreign and local firms. Differences between them arise from different access to local information, familiarity with local business practices and the ability to develop relations of trust. Local firms generally have an advantage in all these, particularly at the start. Foreign investors have established supply linkages with firms overseas. They are reluctant to sever these linkages, especially for demanding inputs and for long-established technical connections. In addition, new affiliates tend to be less knowledgeable about local capabilities, and face higher barriers to establishing strong trust relations. The situation changes over time. As they gain familiarity with suppliers and take on local "flavour" (e.g., by employing local managers), affiliates can come to resemble local firms (WTO, 1998c). In fact, when technological upgrading is needed, as in making an import-substituting activity export-oriented, TNCs can be very effective in improving the local supply base. This can go hand in hand with increased reliance on imported inputs, as overall production is rationalized in line with comparative advantage. In the Mexican automobile industry, for example, liberalization led to intense efforts to improve the local supplier base – often with the entry of foreign companies. It also led to higher import dependence, albeit offset by rapid increases in exports of automotive products (Mortimore, 1995). Japanese TNCs have been transplanting their traditional *keiretsu* links from their home country to host countries ("follow sourcing") (Mani, 1999). One study has shown that the local procurement ratio, measured as the ratio of the value of local procurement to the value of total procurement of the Asian affiliates of Japanese manufacturing firms, increased from 42 per cent in 1986 to 49 per cent in 1992 (Urata, 1998, p. 166).

A converse trend observed in other TNC networks has been to move away from local in favour of intra-firm (international) sourcing. This suggests that in these cases there has been insufficient technological upgrading of potential local suppliers, most often in technologically dynamic activities (Ernst, 1996).

In the long term, the main problem with local sourcing in developing countries lies in supplier capabilities and information gaps on these capabilities rather than in whether the lead firm is foreign or local. The sourcing problems faced by TNCs are greater in their main areas of strength – high technology and export-oriented activities, which have very demanding standards of quality, reliability and delivery. Many TNCs also tend to have large-scale requirements, often beyond the capabilities of local suppliers. However, local firms with similar characteristics also face similar sourcing problems. In many export processing zones, for instance, both local and foreign firms import high proportions of their inputs, even in relatively simple activities like garments, because local upstream suppliers are unable to match the quality, variety and cost standards. For instance, in Indonesia most clothing exporters rely on imported fabrics and accessories (Lall and Rao, 1995). At the same time, as capabilities develop, so does local content. High-technology electronics TNCs in Malaysia have over time raised the level of local purchases, from other TNCs and from local firms (Rasiah, 1994).

Clearly, the best way to raise linkages between TNCs and local firms is to raise the capabilities of potential suppliers. These supply-side measures are preferable to local content requirements, which, like other direct interventions to promote one set of enterprises, can be detrimental to technical efficiency (Moran, 1998). Taiwan Province of China and Singapore used different policies to encourage local procurement and technology transfer without damaging competitiveness in the final producer (box VII.6). Their focus was on providing strong technology support services to SMEs, generally with the support of TNCs. Other countries have put emphasis on developing clusters and networks of local enterprises, and assisted them in building technological capabilities (UNCTAD, 1998f).

b. Other firms and institutions

TNCs can have direct linkages with a variety of local institutions as well as firms. These include local technology institutions such as standards and quality control agencies, research institutes and universities, vocational training centres, financial intermediaries, infrastructure providers and so on. For present purposes, the most relevant ones are those providing technical and skill inputs.

Affiliates tend to lead in the use of the best techniques of quality control, standardization, testing and calibration, particularly when they are producing for export markets. This can lead them to interact intensely with local providers of the relevant services, and in the process to raise their services to international standards. However, where local institutions are well below the standards required – or, as with specialized testing and calibration, simply not able to provide services – TNCs tend to develop in-house capabilities or use foreign institutions. In this case, the spillover benefits will not accrue to the host economy, unless TNCs offer some of their in-house facilities to other firms. As with other spillovers, much depends on the local capability base. If this is able to benefit from TNC interaction, the interaction is likely to be positive; if not, there will not be any interaction.

The situation is similar for government research institutions. Many developing country governments have research laboratories to create and disseminate productive technologies to industry. However, these often lack direct links with the productive sector. The well-staffed ones tend to focus on academic research; the poorly financed and staffed ones do not even do this. However, some countries are reforming their research institutions, inducing them to sell their services and become financially more independent. The results are encouraging. Firms are collaborating with laboratories, where the institutions have good research capabilities and where the firms have in-house R&D experience; in India, even SMEs are starting to place research contracts with laboratories (Goldman *et al.*, 1997). Foreign affiliates are as open to research collaboration as similar local firms. In Mexico, they often take the lead in working with research institutions (Najmabadi and Lall, 1996). India features numerous examples of publicly-funded R&D institutes attracting research contracts from TNCs. The National Chemical Laboratory in India, for instance, reportedly now earns about half its budget from research contracts with industry with foreign chemical companies accounting for around 60 per cent of these contracts. These activities reflect government investment in the skill and R&D base combined with a targeted approach to FDI (table VII.3).

Some studies suggest that the scale of host country R&D is a significant determinant for TNCs' choice of locations for overseas R&D activity. For example, a recent study analysing United States and Japanese TNCs in a sample of 74 host countries found that affiliate R&D intensity

Table VII.3. Collaboration of Indian research centres with TNCs: R&D contracts awarded by TNCs to Indian publicly funded R&D institutes in the early 1990s

Institution	TNC involved	R & D area
IICT, Hyderabad	Du Pont, United States	Pesticide chemistry (by screening agrochemical molecules).
IICT, Hyderabad	Abbot Laboratories, United States	Synthesis of organic molecules and advisory consultancy.
IICT, Hyderabad	Parke Davis, United States	Supply of medicinal plants.
IICT, Hyderabad	Smith Kline and Beecham, United States	Agrochemical and pharmaceutical R&D.
NCL, Pune	Du Pont, United States	Reaction engineering, process modelling for new polymers, nylon research, catalysis, and a scouting programme.
NCL, Pune	Akzo, Netherlands	Zeolite based catalyst development.
NCL, Pune	General Electric, United States	Processes for intermediates of polycarbonates.

Source: Kumar, 1999 based on *Business India* (Bombay), 2 January , 10 April and 9 October 1995; *The Economic Times* (New Delhi), 14 April 1996 and 16 May 1997; *Business Standard* (New Delhi), 16 May 1997; *India News* (the Hague), September 1993; *Chemical Week*, 19 April 1995; and Reddy, 1997.

was positively and significantly related with the scale of R&D activity, the availability of scientists and engineers in the host economy, and the relative cost of hiring R&D engineers of comparable qualification in the home and host country. This suggests that developing countries that are endowed with large numbers of well-trained and comparatively inexpensive researchers, and with a well-developed R&D infrastructure, are well placed to become important hosts of overseas R&D activity in coming years (Kumar, 1998, 1999).

Links between affiliates and local training institutions are fairly common, since all new technologies need shop-floor, technical and managerial training. The need for training depends, of course, on the level of technology introduced (the existing skill base and availability of training in turn influence the technologies selected for transfer). TNCs generally invest significantly in training, often more than local counterparts. They also often bring in training materials and techniques from abroad to supplement the training offered locally. Their awareness of the importance of skill formation sometimes leads them to foster new training institutions (chapter IX).

c. Competing firms

The injection of any new competition stimulates technical efficiency. The entry of world class TNCs into developing countries is even more bracing, especially where firms have been shielded from international markets. Apart from providing a competitive stimulus, TNCs can have spillover benefits: local competitors can learn from their technological or managerial practices, attract their employees or gain access to their technical knowledge.[9]

Spillovers can also be undesirable: TNCs may lower macroeconomic efficiency if they deliberately raise concentration levels, forcing competitors out of business by predatory practices, poaching skilled labour and R&D staff from local firms, or engaging in various restrictive business practices which, among other things, deter technological development. The risk of such behaviour is higher when, as is often the case in developing countries, governments lack efficient competition policy tools and skills (UNCTAD, 1997a).

Less directly, but perhaps more importantly, a strong TNC presence may inhibit the development of local capabilities. Given initial learning costs, potential entrepreneurs may find it impossible to compete with affiliates able to draw upon their parents' technological resources. They may decide to stay in less demanding activities (when TNCs enter high-technology industries) or end up as suppliers to TNCs (where local capabilities have already reached a certain level). The effect is sometimes called "crowding out" (see also chapter VI), but this implies that local enterprises are already present in the activity. It is more the constriction and diversion of the technological learning process in local firms, raising the cost and risk of entering very demanding areas, that raises concern.

It is difficult to analyse empirically the effects of a strong TNC presence. Normal statistical tools are difficult to use to examine crowding out or constricting technological deepening. For instance, no econometric analysis of existing ownership structures in a country can show what the structure would have been if the government had adopted different FDI and technology development strategies. Such non-marginal differences can be analysed only by setting up a "strategic counterfactual" (Lall, 1993); this is very difficult. The next best approach is to compare countries with different FDI strategies but similar levels of industrial development; here one has to control for other national and historical differences, which poses its own problems. Despite these problems, such comparisons are nevertheless suggestive. Take countries that allowed FDI into advanced activities (such as Mexico or Thailand) with those that have restricted their entry to promote local capabilities (such as the Republic of Korea or Brazil). Local enterprises in the latter have developed much greater technological strength, and are now themselves world class TNCs in industries such as automobiles and electronics. However, as noted, there are many cases where FDI restriction failed to catalyse domestic technological competence.

As far as productivity of existing firms goes, statistical analyses yield mixed results on the effect of TNC presence (WTO, 1998c; Kokko, 1996a). There are problems of methodology as well as in interpreting the findings. It is difficult to measure technical efficiency in comparable firms and to control for other factors apart from TNC presence. The effects seem to differ by country, industry and firm characteristics. Much depends on the initial differences between affiliate and local firm technological levels. In many cases, the two sets of firms do not actually compete in the same product segments in a given industry (local enterprises may have already been crowded out), so that there is little that local firms can learn. The extent of spillovers depends on general factor market conditions and the level of development of the economy: there is more when markets and capabilities generally are more developed.

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In sum, the impact of FDI on technology development in local firms is mixed. Restricting TNC entry can help the deepening of local capabilities, but only in rather special conditions. Governments must have the capability to mount effective industrial policies; the skill base must be strong; competition must be ensured, either through an export-oriented trade regime or a functioning competition policy; and support institutions must be able to meet the needs for finance, information and training. In practice, only a few countries have been able to meet these conditions; in many cases, restrictions on FDI have led to technological backwardness. The form and intensity of other spillover effects vary by industry, policy and level of development. They are best when local firms have the capabilities to absorb the knowledge offered by TNCs, least when there is a large technological distance between affiliates and local firms.

3. Technology generation

Formal R&D does not play a significant role in early stages of industrial development. It does, however, become important as capabilities deepen and enterprises use more advanced technologies. Much of this R&D is directed to absorbing, adapting and improving complex imported technologies. (Absorption is a vital function of R&D everywhere – see Cohen and Levinthal, 1989.) But, over time, it shades into genuine innovation. Both are desirable: growing R&D signifies industrial maturity and strength. What, then, is the role of FDI in launching and stimulating local R&D?

As shown earlier, TNCs undertake relatively little R&D in developing countries. A rough indicator is R&D reported by United States TNCs in developing country affiliates. For the mid-1990s, this came to eight per cent of total R&D in affiliates, and only one per cent of parent company R&D (though there may be some underreporting of R&D in developing country affiliates) (table VII.4). R&D in developing country affiliates was, in any case, highly concentrated. Brazil by itself accounted for approximately one-quarter of recorded R&D of United States affiliates in the developing world. The top four economies - Brazil, Mexico, Singapore and Taiwan Province of China – accounted for 77 per cent. At the other end, the least developed countries had no affiliate R&D. The pattern is likely to be similar for TNCs from other industrial countries. While the share of developing countries in affiliate R&D is rising (from 3.5 per cent for United States TNCs in 1989), it remains very small in relation to the total – far smaller than their share in TNC production or investment.

Perhaps this is not surprising. The majority of developing countries do not have the research skills or institutions to make it economical for TNCs to set up local R&D facilities. However, even where local research capabilities have developed, as in some newly industrialized economies (annex table A.VII.2), the distribution of affiliate R&D in the developing world is not related to national R&D propensities. The explanation lies in a host economy's policies. Where the entry of TNCs has been restricted (particularly in complex activities) and technology development promoted by externalized transfers, there is little affiliate R&D activity. Thus the Republic of Korea, with one of the world's highest shares in enterprise-financed R&D in GNP,[10] receives relatively little R&D by United States TNCs, and technology intensive activities are in local ownership. In contrast, Brazil (where enterprise-financed R&D as a percentage of GNP is only eight per cent of that in the Republic of Korea) has a 14 times higher share of United States affiliate R&D spending, although a part of it is the result of R&D capacities obtained as a result of M&As. Most enterprise R&D in Brazil is in the automotive and machinery industries and is TNC-dominated, with the exception of the aircraft manufacturer Embraer, a public sector enterprise. Taiwan Province of China is an intermediate case. It has a strong skill and R&D base, and local presence in high technology activities. At the same time, it has allowed FDI entry, and TNCs have set up R&D bases to exploit its capabilities and facilities.

Table VII.4. Recorded R&D expenditures by foreign affiliates of United States TNCs, 1994

(Million dollars and percentage)

Host economy	Values (Million dollars)	Per cent of total corporate R&D	Per cent of parent company R&D	Per cent of all affiliate R&D	Per cent of affiliate R&D in developing countries
Total R&D by TNCs	103 451	100.0	-	-	-
Of which: parent companies	91 574	88.5	100.0	-	-
All affiliates	11 877	11.5	13.0	100.0	-
Of which: developing economies [a]	901	0.9	1.0	7.6	100.0
Brazil	238	0.2	0.3	2.0	26.4
Mexico	183	0.2	0.2	1.5	20.3
Singapore	167	0.2	0.2	1.4	18.5
Taiwan Province of China	110	0.1	0.1	0.9	12.2
Hong Kong, China	51	-	0.1	0.4	5.7
Malaysia	27	-	-	0.2	3.0
Argentina	21	-	-	0.2	2.3

Source: Data provided by NSB.

[a] Economies receiving more than $20 million in R&D expenditure.

Most affiliate R&D in developing countries is geared towards adaptation or technical support of production or what can be classified as "minor modifications". However, there are signs of deepening of R&D, towards more innovative work (box VII.7). This is partly a process of maturing of R&D effort over time. In some cases, as in the automotive industry in Brazil, it is also the result of a reorientation of the industry from domestic to international markets, calling for rapid upgrading of technologies.

Box VII.7. Strategic R&D by TNCs in developing countries

TNCs have long had R&D units in developing host countries for adapting products and processes to the local conditions, and in a few cases for developing products for local markets. Since the mid-1980s, however, they have also started locating strategic R&D in some developing countries, for developing generic technologies and products for regional or global markets. The main incentives for this are: i) access to highly qualified scientists and engineers as shortages of research personnel emerge in certain fields (due to the mis-match of supply and demand) in industrialized countries; ii) cost differentials in research salaries between developing and industrial countries; and (iii) rationalization of operations, assigning particular affiliates the responsibility for developing, manufacturing and marketing particular products world-wide. The new trends are most visible in industries dealing with new technologies such as microelectronics, biotechnology and new materials. In these technologies, the location of R&D can be geographically de-linked more easily from the location of manufacturing. It is also possible to separate R&D in core activities from that in non-core activities. Developing countries can undertake the latter form of R&D with available skilled manpower. Moreover, these are science-based technologies and personnel with little industrial experience but with a good theoretical training can perform R&D. As a result, countries like India, Israel, Singapore, Malaysia or Brazil serve TNCs as good locations for strategic R&D.

For instance, Sony Corporation of Japan has around nine R&D units in Asian developing countries. It has three units in Singapore, conducting R&D on core components such as optical data storage devices, integrated chip design for audio products and CD-ROM drives, and multimedia and microchip software. It has three units in Malaysia, working on video design, derivative models and circuit blocks for new TV chassis, radio cassette, Discman and hi-fi receiver design, and the design of derivative models of mechatronic products. It has one unit in the Republic of Korea, focusing on the design of compact

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(Box VII.7, concluded)

discs, radio cassettes, tape recorders and car stereos. It has one in Taiwan Province of China, designing and developing video tape recorders, MiniDisc players, video-CDs and duplicators. Finally, it has a unit in Indonesia, focusing on the design of audio products.

Such R&D units often work in close collaboration with science and technology institutes in the host country, with knowledge and technology diffusion going both ways. For instance, Daimler Benz has established the Daimler Benz Centre India in Bangalore to work on projects related to its vehicles and avionics business. Current work includes the interface design of avionics landing systems and smart GPS sensors (intelligent traffic guidance system and development of software), for use by the group's business world-wide. The centre collaborates actively with the Indian Institute of Science in its avionics research.

Source : Reddy, 1999.

Some governments have used targeted FDI attraction and incentives to promote affiliate R&D, as in Singapore (Lall, 1996). And in countries like India, innovative R&D is being undertaken by TNCs to take advantage of plentiful and cheap scientific and engineering skills despite a low overall foreign presence (Reddy, 1997); often, this is in collaboration with domestic firms.

These findings suggest that there are different routes to greater TNC involvement in R&D in developing countries. Where the production base is large and considerable local adaptations or improvements are needed, adaptive R&D is likely to be launched. Over time, adaptive R&D generally shades into genuine innovation, especially where the skill base is good and TNCs gear their operations to world markets. The incidence of local R&D will be higher the more technologically complex and fast moving are the activities undertaken by TNCs. As noted earlier, innovative R&D is attracted most to countries with strong science and research bases. Where countries have been able to build up such bases, a welcoming stance to FDI is likely to attract high quality TNC research investment. Some economies, like Taiwan Province of China and India, have mobilized local research consortia to collaborate with TNCs in developing new technologies (box VII.8 and table VIII.5).

Box VII.8. The role of industry-based research consortia

IBM unveiled its first PC based on the new PowerPC microprocessor, a product made by the alliance of IBM, Motorola and Apple, in New York in June 1995. It was followed one day later by the unveiling in Taipei of PowerPC based products by a group of 30 firms from Taiwan Province of China - the first economy outside the United States to develop a range of state-of-art products based on the new technology. Taiwanese firms did not do this on their own. They were part of an innovation alliance, the Taiwan New PC Consortium, formed by a public research institution, the Computing and Communications Laboratory (CCL). The Consortium was set up in 1993 to bring together firms from all parts of the information technology industry in Taiwan Province of China. Its specific purpose was to transfer, master and diffuse the new PowerPC technology over the whole range of products from PCs and peripherals to software and multimedia applications, as well as semiconductor manufacturers that would make their own versions of the new chip. The firms involved were relatively small by international standards, and CCL brought them together and negotiated on their behalf with IBM and Motorola.

This was not the only instance of strategic alliance formation by the authorities of Taiwan Province of China to stimulate innovation and take industry to technological frontiers. The Industrial Technology Research Institute (ITRI) led in the formation of some 30 consortia in the IT industry over the 1990s. This focused on products like laptop computers, high-definition television, videophone, laserfax, broadband communications, digital switching devices, smart cards and so on, helping firms to move up the technology chain. In each case, ITRI identified the products, tapped channels of technology transfer, mobilized the firms, handed the complex negotiations with developed country firms, and covered intellectual property issues. The individual firms developed their own versions of the jointly developed core products and competed in final markets at home and abroad. Their size limited their ability to do this on their own.

Source : Poon and Mathews, 1997.

Table VII.5. Illustrative cases of global R&D centres and R&D joint ventures in India

Institution/ year partnership was established/ location	TNC involved	Focus and objectives	Rationale
Global or regional R&D centres set up by TNCs in India			
Astra Research Centre India, Bangalore, 1986	Astra AB, Sweden	Discovery of new diagnostic procedures and therapeutic products with tools of molecular biology, immunology, cell biology.	Availability of highly qualified and talented manpower; low manpower and R&D costs; access to leading institutes e.g. IISc, Bangalore.
Texas Instruments India, Bangalore, 1986	Texas Instruments, United States	CAD software for IC design and other applications, IC design of application specific memory products, digital signal processors, memories and mixed signal ICs.	Abundance of R&D personnel with strong background in theoretical sciences and engineering, strategic presence in Asia-Pacific region, English speaking environment.
Asia-Pacific Design Centre, India, 1992	SGS-Thomson Microelectronics, France	Central R&D for new circuits and libraries, mixed analogue design, memories, VHDL modeling, synthesis and regional R&D design, layout and debugging of custom ICs.	To utilize the country's highly skilled but cheap technical manpower.
Unilever India Pvt. Ltd, Bangalore, 1996	Unilever, United Kingdom/ Netherlands	As one of the five global R&D centres worldwide, to upgrade various Lever products across globe, to serve as a global tea R&D centre.	To tap the rich scientific talent in India.
D-B Research Centre India, Bangalore, 1996	Daimler-Benz, Germany	Among others, interface design of avionics landing systems and Smart GPS sensors and other projects related to vehicles and avionics business.	Availability of scientific talent in India, ability to draw upon the R&D facilities of IISc among other leading public-funded institutes.
TNCs setting up R&D joint ventures with Indian companies			
Ranbaxy Labs. India, New Delhi, mid-1990s	Eli Lilly, United States	Joint R&D for process development for drugs.	Ranbaxy's ability to develop a cost-effective process for synthesis of Cefaclor, among other products.
Hindustan Aeronautics capabilities Ltd., Bangalore, early 1990s.	British Aerospace, United Kingdom	CAD packages, software applications in management, manufacturing, design and real time info. systems.	Complementary design of HAL.

Source: Kumar, 1999 based on *Business India* (Bombay), 2 January, 10 April and 9 October 1995; *The Economic Times* (New Delhi), 14 April 1996 and 16 May 1997; *Business Standard* (New Delhi), 16 May 1997; *India News* (the Hague), September 1993; *Chemical Week*, 19 April 1995; and Reddy, 1997.

However, the evidence also suggests that few developing economies are likely to benefit from the spread of TNC R&D in the near future. Among the developing countries receiving FDI inflows, many lack the base of technical skills to mount a significant research effort; they have not developed significant science bases or induced local firms to undertake R&D (annex table A.VII.2). Those that have done so managed it by restricting FDI inflows and undertaking comprehensive industrial and skill development policies (Ernst, 1996; Lall, 1996; UNCTAD, 1995b). However, their strategies are difficult to replicate. Even the economies that relied mainly on externalized technology transfer in the past are now more open to FDI, partly because of external pressures and partly because of the sheer scale and complexity of technical change. A number of policy tools nevertheless remain for developing countries to choose from, the subject addressed below.

D. Conclusions and policy implications

Technology flows across economies in many ways, disembodied and embodied. Its effective transfer and subsequent development depend on the channels of transfer and, increasingly, on local abilities to use it. With a growing reliance on information and rapid change, the abilities needed have become more varied and skill-intensive. As a result of technological progress, the channels for transferring technology have expanded and often become cheaper, though at the advanced end of the spectrum access may have become more difficult. The costs of innovation, the spread of international production and policy liberalization have increased the role of TNCs in all aspects of technology. As commercial enterprises, TNCs in principle do not have an interest in transferring knowledge to and supporting innovation in foreign affiliates beyond what is needed for the production process or product at hand.

Developing countries therefore cannot expect that, by simply opening their doors to FDI, TNCs will transform their technological base. Deficiencies in technological learning and transfer in developing countries can mean that markets do not create technological dynamism. At best, they can lead to a better use of static endowments but not to the continuous upgrading that competing in the new context requires. To tap their potential, host governments therefore have a role to play in promoting local learning and developing skills and institutions.

Potentially, TNCs have much to offer in developing local capabilities. What technologies and functions they actually transfer to particular locations, however, depends greatly on local capabilities. There is thus again a role for policy in upgrading capabilities to optimize the transfer of TNC technology and encourage its dissemination. Moreover, there is also a role for policy in attracting higher quality FDI: providing better information to prospective investors and ensuring that their needs are met can be a vital tool of technology development.

Experience shows that there is a continuum of strategies with regard to the transfer, generation and diffusion of technology. At one end is a self-reliant or indigenous technology policy, which relies entirely on domestic firms and institutions and restricts technology transfer. At the other end is a strategy that relies almost exclusively on internalized technology inflows, with the bulk of technology transfers taking place within TNCs. In the middle are strategies that combine indigenous technology development with internalized inflows in varying combinations. The nature of government policy differs accordingly. The indigenous strategy calls for strong government intervention. The internalized strategy may call for policy intervention where the host government seeks to accelerate FDI entry into higher technological segments, or it may involve relatively little intervention where the government is content to leave the evolution to market forces.

The potential of these alternative strategies on the development of domestic capabilities is as follows:

- The rationale of an *externalization-oriented* strategy is to foster domestic capabilities, in general or in selected strategic industries, and to encourage indigenous technology development. The role of FDI is restricted, with a bias towards technology inflows in externalized forms. Some countries try to foster national flagship firms (Dunning, 1998a) in high-technology industries, providing them with protected domestic markets and subsidized credit. Governments support domestic enterprises in mastering increasingly complex technologies, and create or support R&D centres (box VII.9). This approach was adopted, at different periods, by economies such as the Republic of Korea, China, India, and Brazil. Indonesia and Brazil, for example, developed an aircraft industry in this fashion; Malaysia and India used it to build a national automobile industry.

  The strategy is risky, and the results have been mixed. It has allowed economies to establish medium-technology industry and products with a competitive edge. Enterprises nurtured under this strategy have become transnational themselves - India's motorcycle industry is a case in point. It may be more difficult, however, to establish high-technology industries, unless the government is able, as in the Republic of Korea, to invest massively in human capital and force domestic firms to orient their activities largely to export markets.

This strategy is difficult to replicate. It needs a strong base of technological skills, entrepreneurs able and willing to undertake risky technological effort, and an incentive regime that shelters learning while ensuring that there is competition, for example through anti-trust regulations[11] or by imposing export discipline. It also needs a government bureaucracy and other institutions able to handle these tools efficiently and flexibly without being hijacked by particular interests; and it needs resources to finance expensive R&D.

- An *internalization-oriented* strategy relies heavily on technology transfers via FDI. The rationale is to access technology as rapidly as possible, without investing public resources, and without waiting for domestic firms to develop technological capacities. There are two sub-strategies. In one, the economic role of government is minimal - ensuring a stable macroeconomic environment and good infrastructure. This strategy might lead to the exploitation of static comparative advantages, but it may not push the local technological frontier or promote industrial upgrading and extensive local linkages. In the other, the government may play a proactive role in targeting TNCs and inducing them to upgrade technologies and enter complex activities. This approach is also difficult to replicate. It requires very efficient targeting and massive investments in skills and institutions, difficult for large economies with a great number of domestic firms that need incentives or support to upgrade technology.

Box VII.9. FDI and technology development strategies in the Republic of Korea

The Government of the Republic of Korea combined selective import-substitution with forceful export promotion, protecting and subsidizing targeted industries that were to form its future export advantage. In order to enter heavy industry, promote local R&D capabilities and establish an international image for its exports, the Government promoted the growth of large local private firms, the *chaebol*, to spearhead its industrialization drive. Korean industry built up an impressive R&D capability by drawing extensively on foreign technology in forms that promoted local control. Thus, it was one of the largest importers of capital goods in the developing world, and encouraged its firms to obtain the latest equipment (except when it was promoting particular domestic products) and technology. It encouraged the hiring of foreign experts, and the flow (often informal) of engineers from Japan to help resolve technical problems.

The Government permitted FDI only when other means of accessing technology were not available; it consistently sought to keep control firmly in local hands. Foreign majority ownership was not permitted unless it was a condition of having access to closely held technologies, or to promote exports in internationally integrated activities. Some TNCs were induced to sell their equity to local partners once the technology transfer was complete. In the initial stages of development of important industries like electronics, however, TNCs played a major role in launching export-oriented assembly. Once it became clear that the pace of technological upgrading of foreign affiliates was slower than the Government desired, it pushed local firms to acquire independent capabilities. These capabilities ranged from the mastery and improvement of imported technologies to the absorption of foreign management practices and, later, to innovative R&D.

The authorities also intervened in major technology contracts to strengthen domestic buyers. It sought to maximize the participation of local consultants in engineering contracts to develop basic process capabilities. The 1973 Engineering Service Promotion Law protected and strengthened domestic engineering services. The Law for the Development of Specially Designated Research Institutes provided legal, financial and tax incentives for private and public institutes in selected activities.

Technological efforts were supported in several ways. Private R&D was directly promoted by incentives and other forms of assistance. Incentive schemes included tax-exempt technology development reserve funds, and tax credits for R&D expenditures as well as for upgrading human

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(Box VII.9, concluded)

capital related to research and setting up industry research institutes. The Government also gave accelerated depreciation for investments in R&D facilities and a tax exemption for 10 per cent of cost of relevant equipment. It reduced duties on imported research equipment, and reduced excise tax for technology-intensive products. The Korea Technology Advancement Corporation helped firms to commercialize research results. A six per cent tax credit or special accelerated depreciation provided further incentives.

The Government directly financed a large number of projects judged to be in the national strategic interest. Specifically, it supported three R&D programmes: the Designated R&D Programme, the Industrial Technology Development Programme and the Highly Advanced National Project Programme. By 1993, the Government had invested around $3.5 billion in these programmes.

The import of technology was promoted by tax incentives: transfer costs of patent rights and technology import fees were tax-deductible; income from technology consulting was tax-exempt; and foreign engineers were exempt from income tax. In addition, the Government gave grants and long term low interest loans to participants in "national projects", and gave tax privileges and official funds to private and government R&D institutes to carry out these projects. The Korea Technology Development Corporation provided technology finance.

However, the main stimulus for industrial R&D was less the specific incentives to R&D than the overall incentive regime. This created the *chaebol*, gave them a protected market to master complex technologies, minimized reliance on FDI, and forced *chaebols* into international markets where competition ensured that they would have to invest in their own research capabilities. This is why, for instance, the Republic of Korea has 35 times higher R&D by industry as a proportion of GDP than Mexico (with roughly the same size of manufacturing value added), a country that has remained highly dependent on technology imports. At the same time, it may not have created sufficient innovative capabilities on the part of the *chaebol*, which excel more at implementing rather than creating state-of-the-art technologies.

Sources: Lall, 1996; Ernst, Ganiatsos and Mytelka, 1998a.

In practice, most developing countries combine these two strategies, retaining a role for policy in shaping and directing resource allocation and technology transfer. This may require governments to target complex technologies and induce TNCs to upgrade local functions. This strategy is usually combined with measures to build local technological and innovatory capacity, and promote linkages with the domestic economy, working with a variety of institutions (such as departments of enterprise development, labour or education). It calls for a strong administrative infrastructure and skill base, able to select technologies, target and bargain with TNCs, and handle incentives efficiently. Policies towards technology transfer by TNCs need to be tailored to the context in which they take place, in particular the technology involved, capabilities of governments and recipient enterprises, and the learning environment. What is appropriate for high technology or a highly industrialized economy may not necessarily be appropriate for a simple technology or a less developed country. The less developed a country and the lower its domestic capabilities, the more it might resort to the internalization strategy, using FDI to overcome obstacles to technological upgrading. But it needs to be borne in mind that technologically competent enterprises can exist even in low-income economies and may well be in a position to absorb or even generate technology.

Government capabilities are crucial. Experience shows that certain types of interventions can impose high costs on an economy without corresponding gains in technological capacity. Import-substituting regimes that try to build capabilities behind high levels of tariff protection, without complementary policies to induce technological mastery and stimulate and support technological change, may result in an inefficient technological base. A critical element here is strategic planning, the ability to conceptualize the capacity-building process in an integrated fashion, across the skill, financial, infrastructure and technological markets that firms need to develop their capabilities – initiating a virtuous cycle of continuous upgrading and innovation.

However, the new technological and policy context makes it more difficult to promote local technology development. The sheer pace of technological change makes technology strategies more risky and expensive. Not too many developing countries are in a position to create broad and deep domestic capabilities in the immediate future. In the case of developing countries, therefore, especially the least developed, host country efforts need to be complemented by international efforts to foster effective transfer of technology to these countries. The issue of transfer of technology to developing countries has been recognized in various multilateral fora since the 1970s (box VII.10).

Box VII.10. Transfer of technology in multilateral fora

The issue of transfer of technology to developing countries has been an important component of the international economic agenda since the launching, under the aegis of UNCTAD, of negotiations on an international code of conduct on transfer of technology in the 1970s. At that time, technology was generally assumed to be like any other product, and the process of technology transfer to be effected as any other transaction between a seller and a buyer. The "tacit" elements of the transfer or the role of local learning, were not given much consideration. Thus, the problem of transfer of technology was seen largely in terms of supply-side constraints resulting from monopolistic behaviour and associated restrictive business practices in the international technology market. The code of conduct was proposed as a solution to the problem, as perceived at the time, by liberalizing trade in technology and introducing guidelines on the terms and conditions of transfer of technology to developing countries.

Although the negotiations on the draft code helped to highlight the concerns and problems of developing countries regarding transfer of technology, they did not lead to concrete action at the multilateral level as its initiators had hoped for. In the end, the negotiations on the draft code were overtaken by other developments. These include, in particular, the liberalization of markets across countries, rapid advances in technology, the growing knowledge-intensity of production as well as its diffusion across sectors, and the emergence of innovation and learning as important determinants of competitiveness. These developments had an impact on the way technology and the process of technology transfer are perceived in the new context. In the past, much emphasis was placed on the transfer of technology *per se,* rather than on its diffusion. Consequently, policy prescriptions were focused on defensive measures to remedy disfunctions in the international market for technology. Today defensive measures are less in favour on the grounds that market imperfections are best addressed by measures aimed at improving the contestability of markets B hence the importance of competition policy B rather than by interventions intended to modulate forcibly the conditions under which the transfer of technology takes place. Increasingly, the focus is on effective transfer of technology which includes the diffusion and generation of technology locally.

Although some developing countries have succeeded in building local technological capability, the transfer of technology from abroad remains the most important source of technology for most developing countries. The facilitation of such transfer through international measures that complement host country efforts to build the capability of local firms to select, acquire, adapt and master the technology continues, therefore, to be an important issue for developing countries. In spite of the failure of the code negotiations, the issue has thus been a recurrent theme in multilateral discussions that have taken place in recent years. In the context of multilateral environmental agreements, for example, the issue of transfer of technology has been a regular feature of any such agreements negotiated since the Rio de Janeiro Earth Summit. Thus, the Rio Declaration invited industrialized countries to take "all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how" (article 4.5). In the context of the TRIPs Agreement (article 67) (WTO, 1995), specific reference is made to technology transfer problems of the least developed countries (LDCs); it states that industrialized countries "shall provide incentives to enterprises and institutions - for the purpose of promoting and encouraging technology transfer - in order to enable them [the LDCs] to create a sound and viable technological base" (TRIPs Agreement - article 67) (WTO, 1995). An analogous treatment is found in the GATS Agreement (article IV) (WTO, 1995).

Source: P. Roffe. and T. Tesfachew, 1999.

The new rules of international trade, investment and the protection of intellectual property rights have rendered many instruments used in the past by the then newly industrializing economies difficult to apply. As regards industrial policy, for instance, it is becoming harder to impose local content rules, give infant industry protection, or subsidize targeted activities. Nevertheless, with regard to technology policy, there is some scope for developing countries to provide technology support services and finance for innovation.[12] Also, a number of policy options remain to strengthen the "supply side". The main ones include minimization of business transaction costs, human capital formation, domestic enterprise development, cluster promotion, encouraging closer links between industry and research, and strengthening physical infrastructure. These are the basic building blocks of competitiveness strategies applied in many mature industrial countries, and they are applicable in developing ones as well. Taking general supply side measures as given, let us consider the menu of options to encourage more specifically the transfer, diffusion and generation of technology by TNCs fully recognizing, of course, that the various issues are closely intertwined.

1. Transfer

The most important determinants of technology transfer are the levels of skills and capabilities of an affiliate, its competitors and the supplier network, and the competitive environment facing the affiliate. The higher the level of local capabilities and the more competitive the environment, the better the quality of the initial transfer and the more rapid its upgrading. TNCs invest in strengthening in-house skills and technical knowledge to the extent necessary to achieve efficient production but not necessarily to raise capabilities to the next level of technology, or promoting technology transfers to local firms. Possible policies are:

- Attracting TNCs – from developed and developing countries – to specific high-technology industries like computers and computer components, software development, or biotechnology. Such targeting can be direct (a positive list of industries open to FDI), or indirect (various incentives). For the latter, instruments include fiscal (tax) deductions, duty drawback provisions and financial incentives (grants and low interest rate loans). This can be encouraged by home and host country ministries, boards of investment or chambers of commerce, and it can also include information dissemination. Instead of targeting specific industries, governments could offer incentives to foreign investment projects whose products or processes are new to the country. This approach gives the government more flexibility than simply using a list of "promoted" industries; however, there may be problems in defining new technologies and in placing considerable discretionary power in the hands of government regulators.

- Offering incentives to existing investors to move into more complex technologies and to increase or upgrade the technological R&D undertaken locally. This involves both upgrading all factor inputs that TNCs need (infrastructure, skills, information and so on) and giving targeted incentives to launch new functions by existing affiliates or to attract technology-intensive sequential investment. The nature and level of incentives can be geared to the specific technological objectives of a government, and they can be designed in consultation with TNCs and local firms, drawing on successful experiences. A variant of this strategy is to give incentives for investment in productivity-enhancing equipment, such as process automation or robotics, regardless of the industry in which an investment is made. Singapore (box VII.11) and Ireland are good role models.

- Developing industrial parks with high quality infrastructure to attract high technology investors. Government can either develop these parks itself or it can grant incentives for private developers. Governments can go further and develop industrial parks for specific high-technology industries such as computer software or hardware. If properly executed, industrial parks can be a very effective means of attracting high-technology investors. Governments can also enter the pre-production stage by fostering high-technology entrepreneurs in technology incubators located in universities or technological institutes in an industrial park.

- Attracting TNCs into natural resource processing and inducing greater local value added in resource-based exports. This strategy can lead not only to increased domestic value added but also to considerable technology transfer. For example, bans on the export of raw hardwood timber from Indonesia and the Lao People's Democratic Republic led to the creation of furniture, flooring and plywood industries in conjunction with TNCs. The Government of the Philippines induced foreign copper mining companies to form a new enterprise to smelt and refine copper. However, there is a risk that such programmes might convert valuable natural resources into less valuable finished products. This has been the case with some agro-industrial exports where the unit value of the processed product is lower than that of fresh produce or unprocessed products (UNCTAD, 1997c).

- Using TNCs present in a country to attract investment by their suppliers overseas. Suppliers are often small companies with highly specialized expertise, not accustomed to operating abroad. These might be induced to relocate if offered financial or institutional support. To attract such investors, host governments may need to relax joint venture or minimum capital requirements.

- Changing the competitive environment and the existing incentive structure to promote the use of world-class technologies and management methods, liberalizing the trade regime or promoting exports.

- Improving the skill and training base. Policies have to both raise the quality of the labour force outside the firm and encourage more training of employees within the firm or in special institutions. The former involves general education policies, the latter addresses the specific skill needs of TNCs (box VII.11). These options are discussed in more detail in chapter IX.

- Collecting, organizing and disseminating information about the technical, research and training facilities in the host country.

- Improving technology access for local enterprises, by providing information on foreign and local sources of technology.

Box VII.11. Singapore's strategy to upgrade foreign affiliate technology

After a brief period of import substitution, Singapore switched to free trade. It pursued growth by aggressively seeking and targeting FDI, while raising domestic resource mobilization by various measures. Moreover, it chose to deepen its industrial and export structure and used a number of selective interventions to move from labour-intensive to capital, skill and technology-intensive activities. Its technology acquisition policy was directed at consciously acquiring, and subsequently upgrading, the most modern technologies in highly internalized forms. This allowed it to specialize in particular stages of production within global systems of TNC production, drawing on the flow of innovation generated by the firms and investing relatively little in its own innovative effort.

To attract FDI while inducing it to upgrade, Singapore developed a highly efficient system of attracting and targeting TNCs. To support this targeting, it invested heavily in education, training and physical infrastructure. It developed an industrially-geared higher technical education structure, together with one of the best systems in the world for specialized worker training. Some of the leading training centres were set up jointly with TNCs, one from India. The Tata group started the precision instruments training centre.

The country's FDI policies were based on liberal entry and ownership conditions, easy access to expatriate skills, and generous incentives for the activities that it was seeking to promote. It set up the Economic Development Board (EDB) in 1961 to co-ordinate policy, offer incentives to guide foreign investors into targeted activities, acquire and create industrial estates to attract TNCs, and generally to mastermind industrial policy. At times, it deliberately raised wages to accelerate technological upgrading, though in the mid-1980s a sharp rise in wages had to be modified to restore competitiveness. Over time, TNCs were drawn into the industrial policy- making process, and the EDB emerged as one the world's most successful IPAs.

/ ...

(Box VII.11, concluded)

The public sector played an important role in launching and promoting activities chosen by the Government, acting as a catalyst to private investment or entering areas that were too risky for the private sector. While the main thrust of Singapore's technology import policies was to target FDI, in recent years the Government has also sought to increase linkages with local enterprises by promoting subcontracting and improving extension services. The Government itself has launched R&D centres to create new capabilities in the economy, which would later attract TNC participation. A good example is the Institute for Molecular and Cell Biology, established in a university and now securing research contracts from leading pharmaceutical TNCs.

The decisions of TNCs about what new technologies to bring into Singapore were influenced by the incentive system, the provision of excellent infrastructure, and the direction offered by the Government of Singapore. It itself responded (or anticipated through proactive planning and consultation) by providing the necessary skilled manpower, often in consultation with TNCs. In many instances, it was the speed, efficiency and flexibility of Government response that gave Singapore the competitive edge compared with other competing host countries. In particular, the boom in investment in offshore production by TNCs in the electronics industry in the 1970s and the early 1980s created a major opportunity. The Government seized it by ensuring that enabling support industry, transport and communication infrastructure, as well as skill development programmes were available to attract these industries to Singapore. This concentration of resources helped the country to achieve significant agglomeration economies and hence establish strong first-mover advantages. It was able to attract related industries like the disk-drive industry, where all the major United States disk-drive makers now have plants in Singapore. These industries demanded not only electronics components and PCB assembly support, but also various precision engineering-related supporting industries such as tool and die, plastic injection moulding, electroplating and others. These supporting industries were actively promoted by the government as part of a deliberate cluster promotion strategy.

As labour and land costs rose, the Government of Singapore used the opportunity to encourage TNCs to reconfigure their operations on a regional basis. A special programme was launched to make Singapore attractive as a regional headquarters for TNCs, and for regional marketing/distribution/service/R&D centres to support manufacturing and sales operation in the region. To promote such a reconfiguration, new incentives such as the regional headquarters scheme, international procurement office scheme, international logistics centre scheme, and the approved trader scheme were introduced.

Sources: Lall, 1996; Wong, 1997.

2. Diffusion

The diffusion of technology by TNCs to vertically and horizontally linked enterprises again depends greatly on their receptive capabilities and the competitive environment. Apart from general measures discussed above, specific measures should be considered to raise linkages between TNCs and local suppliers, including SMEs:

- Encouraging technology alliances between local firms and TNCs by offering fiscal benefits for R&D or the exploitation of its results.

- Improving extension and training services to strengthen the capabilities of SMEs.

- Assisting enterprises in building local brand names that might be attractive to TNCs.

- Developing backward linkage programmes between TNCs and domestic suppliers. These involve intensive consultation, training and technology transfer between TNCs and potential domestic suppliers. In exchange for incentives in the form of inexpensive infrastructure, Mattel in Indonesia, for example, agreed to develop domestic suppliers of inputs to its plastic toys production. Similarly, under its Local Industries Upgrading Programme (LIUP), the Government of Singapore encourages TNCs to "adopt" a group of SMEs and transfer technology and skills to them. It pays the salary of a full-time procurement expert to work for specified periods with the adopted firms and help them upgrade their production and management capabilities to the standards required.

- Providing venture capital to encourage TNC employees and others to establish enterprises that tap the skills and technologies developed by TNCs. For example, Malaysia has developed a special fund to provide entrepreneurs with low-cost capital. In Indonesia, government policy mandates that banks allocate a specified percentage of total loans to SMEs.

- Devising programmes to invite nationals living overseas, especially those with a higher education, to return as investors. Several economies, such as Singapore, India, and Taiwan Province of China have such programmes offering, for instance, attractive financing packages to expatriates who start high-technology companies.

- Adopting effective competition policies to stimulate efficient domestic competition and prevent restrictive business practices and abuse of monopoly positions by affiliates.

- Providing, or enhancing the performance of, the technology infrastructure. This would include establishing or enhancing quality standardization and metrology organizations, and providing support for upgrading in compliance with standards such as ISO 9000 or 14000.

- When privatizing technology-intensive state-owned enterprises, a government can insert clauses, for example, on maintaining existing R&D facilities or disseminating technology.

3. Generation

Apart from measures already covered under technology transfer and the upgrading of affiliate functions, those for encouraging local R&D include:

- Encouraging contract R&D with local research institutions and universities by broadening the research areas of the institutions (to make them more industry-oriented) and strengthening their research capabilities. Governments may also consider underwriting part of the cost of approved research contracts and setting up new research institutions in areas of special interest to TNCs. Between 1985 and 1995, for example, Singapore set up a number of research centres focusing on technologies such as biotechnology and electronics. This helped to develop pre-competitive technologies, provide services to companies and deliver specialized training.[13] (Examples from India are reported in table VII.3.)

- Developing human resources for R&D in specialized disciplines (for example, telecommunication software or semiconductor design). This involves supporting local universities and other institutions of higher learning and adapting their curricula. It may also entail investment by foreign universities, to accelerate technology transfer, dissemination and generation and to raise the educational and skill levels of the labour force. Malaysia and South Africa, for example, are following this approach.

- Developing university research laboratories and research institutes. A government can connect such laboratories and institutes to TNC investors and to companies in other countries that contract for their services. India has been successful in following this strategy (table VII.5).

- Offering incentives for affiliates to obtain "product mandates" from parent companies. The offer of fiscal benefits or grants linked to the upgrading of affiliates to handle an entire product, from design to marketing, can be effective where other capabilities are present in a host economy.

- Offering incentives for local R&D more generally, perhaps adapting the incentives to the nature of the technology and research undertaken. Advanced work in strategic areas such as information technology and industrial electronics can, for instance, be given stronger incentives than others.

- Developing local enterprises, including clusters and networks of high-technology firms and enterprises active in niche markets, to attract knowledge-intensive FDI (Kumar, 1998; UNCTAD, 1998d).

- Providing tax incentives for TNCs that undertake R&D in the host country, provide grants or provide government cost-sharing in R&D projects. Examples include tax deduction of R&D expenses, duty free importation and accelerated depreciation for research equipment. Some countries allow for a 200 per cent tax deduction on such expenses.

- Accelerating technology generation by enforcing intellectual property rights. This encourages technology generation by domestic companies as well as by TNCs. However, unnecessarily strict enforcement of intellectual property rights may impede efforts to reverse-engineer foreign technologies, an avenue for technology generation in many developing countries. It may also raise the cost of technology transfer.

- Supporting local innovation systems. This entails some form of strategic planning – or vision - regarding a country's future technological development. This, too, will serve to make developing countries a destination for affiliate-based and other R&D.

- Tapping overseas development assistance flows and funnelling them into skill development in general, and R&D-related activities in particular.

4. The international dimension

These policy efforts regarding the transfer, diffusion and generation of technology of host countries need to be complemented by international measures. A new positive agenda is needed to take into account recent developments, including the evolution of thinking on technology and the process of technology transfer (Roffe and Tesfachew, 1999). In designing such an agenda as a basis for discussions on international instruments, the following elements could be taken into consideration:

- Examining the policies and incentive structures that technology supplier countries could take to encourage the transfer of technology to developing countries. Indeed, a number of home countries have already introduced tax and other incentive policies with this objective in mind. International negotiations could consider how such an approach could be formalized and institutionalized through multilateral agreements.

- Establishing a transfer-of-technology facility to undertake, among other things, assessments of technology needs of developing countries, in particular the least developed countries; to provide information on foreign technology markets and the legal and administrative frameworks in force in various economies; and to encourage networks and partnerships that promote transfer of technology.

- Defending the interests of both creators and users of technology by maintaining an appropriate balance between the incentives to innovate and the need for adequate diffusion of technical knowledge among firms and countries, and by introducing safeguards to prevent abuse of intellectual property rights.

- Strengthening the negotiating capacities of firms and governments in developing countries, especially in the areas of contract negotiations and other conditions and clauses of transfer of technology.

- Creating conditions for international cooperation in R&D activities and the mechanisms for the transfer and diffusion of the results of publicly-funded R&D activities that have direct bearing on technological capability-building efforts of host countries. This might include support to inter-country research networks (UNCTAD, 1999f and g).

- Providing the necessary institutional and financial means - including dedicated overseas development assistance flows - for the above activities.

Given the role that technology plays in development, it is not surprising that the issue remains on the international agenda. Countries – and firms – could benefit if international efforts in this area could yield tangible results.

Notes

1 See Nelson, 1993. For an extensive discussion of national innovation systems, see for example UNCTAD, 1999f. For a discussion of the relationship between innovation and economic growth, see Cantwell, 1998, and Mytelka, 1998b.

2 One problem with patents is that they must be put into production before they can be considered "technological change" or an "innovation". Many patents never are.

3 It needs to be borne in mind that data on R&D are not necessarily comprehensive. Some research activities, notably in developing countries, may not be fully reflected in available statistics.

4 The data, from NSB, 1998, are for 1995. Another proxy, on the "output" side of innovative effort, are patents: of all patents taken out in the United States between 1963 and 1995, 62 per cent were of United States origin. Of non-United States held patents, Japan accounted for 35 per cent and Germany 21 per cent. Between 1977 and 1996, the top five countries (all of which are OECD members) accounted for 78 per cent, and the top 10 for 95 per cent, of patents in the United States (Kumar, 1998). However, developing country firms whose main operational activities, or markets, are outside the United States may not apply for a patent there, but instead register them in other regions such as the European Union. Moreover, the costs of patenting in the United States are fairly high. So, R&D output, based on United States patent data, may underestimate the innovation activity of developing countries.

5 For instance, in an exercise conducted for this report, outward FDI by the leading 35 outward investors was found to be significantly and positively correlated with R&D propensities. R&D was also highly correlated with the share of technically advanced products in exports and domestic skill endowments. The share of advanced exports was positively related to outward FDI: direct investment and exporting complex products exploited the same set of advantages – innovation and skills.

6 See Mytelka, 1999a, for the working of this process in the telecommunications equipment industries.

7 On the increasing delinking of innovation from production, particularly in the electronics industry, see, for example, Sturgeon, 1997. Sturgeon argues that the United States electronics industry is developing a new model of industry organization where innovators are out-sourcing increasing shares of their production. The producers are becoming specialized "merchant suppliers" that are building turnkey production networks that can supply a number of firms with total manufacturing capability. Thus, in this industry, the traditional links between innovation, production and integration appear to be breaking down, giving the innovators greater flexibility.

8 Patents as a measure of technological activity have advantages over R&D. Patent data are available for longer periods, in more detail and for more countries. In any case, both give very similar geographical distributions (Patel and Pavitt, 1998).

9 For a survey see WTO, 1998c.

10 The data here refer to enterprise-financed R&D as a proportion of GNP, and are calculated from UNESCO, 1997.

11 For an extensive analysis of the role of competition policy to ensure competitiveness, see UNCTAD, 1997a.

12 Developing country governments can use technology-related performance requirements and certain government subsidies to enhance their technological capability. Under the Agreement on Subsidies and Countervailing Measures, subsidies to R&D by firms are non-actionable, and hence WTO-conforming. This requires, *inter alia*, that assistance is limited to specified costs (personnel, instruments, equipment, land and buildings, consultancy, overheads and running costs up to 75 per cent of the costs of industrial research or 50 per cent of the costs of pre-competitive development activity (article 8.2 (a)). Under the General Agreement on Trade in Services (GATS), performance requirements - including technology-related ones - can be used as conditions or limitations on market access and national treatment in those sectors in which countries make specific commitments (GATS Articles IV, XVI, XVII and XIX). The TRIMs Agreement does not classify technology-related performance requirements as inconsistent with the obligation of national treatment and the obligation of general elimination of quantitative restrictions provided in GATT 1994.

13 For a description of beneficial links between research institutions and enterprises, see Porter, 1998.