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CHAPTER VI
DEVELOPMENT IMPLICATIONS

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DEVELOPMENT IMPLICATIONS

A. New development opportunities in the making

R&D is among the highest value-added activities undertaken by firms. Its internationalization affects the allocation of knowledge and human resources across countries and creates links between domestic actors and the R&D activities of TNCs. It deepens technology transfer – from simply transferring the *results* of innovation to transferring the *innovation process* itself. Until recently however, with the exception of some production support and adaptive R&D for local markets, FDI in R&D has been out of the reach of most countries outside the Triad. The new trend of TNCs setting up global R&D facilities in some developing countries is still in its infancy, but it is important. It has significant long-term implications for host and home countries alike (table VI.1).

Internationalization of R&D can benefit host developing countries in several ways. It can serve as a training ground by providing challenging, high-skill jobs to scientists and engineers. It can create new research skills and thereby help enhance human resources in a host country. It can bring in new knowledge and research know-how, and it can generate knowledge spillovers to domestic enterprises and other organizations, thus stimulating an R&D culture in a host economy. Growing R&D competence can, in turn, help host countries move up the value chain and into new areas of dynamic comparative advantage. In an increasingly technology-based setting this can be of immense benefit.

This does not mean that all developing countries are able to seize these opportunities and reap the benefits; TNC R&D is going to relatively few countries (chapter V). Nor does it mean that all its development benefits will materialize automatically. There are potential costs. The net outcome depends crucially on the type of R&D involved and on the economic context, including the host country's technological capacities, and policy and institutional framework (chapter VII).

Overseas investment in R&D also has economic implications for TNCs and their home countries. R&D in developing countries can enhance the innovative and productive efficiency of TNCs by allowing them to combine their technological strengths with foreign assets. They may be able to acquire new technological assets and thereby enhance their global competitiveness. The home economy may benefit from increased exports, reverse technology transfers and improved R&D efficiency of their firms. Developing home economies can reap similar benefits; indeed, the benefits to them may be even higher, because their enterprises can tap into global innovation centres by establishing an R&D presence.

At the same time, R&D internationalization may trigger concern in home countries. Some fear that, as lead firms expand their production and R&D activities abroad, the R&D of related and supplier TNCs may follow, thus leading to a "hollowing-out" effect. As firms restructure their R&D activities internationally, some knowledge workers may have to shift to new jobs, which could involve adjustment costs associated with creating new skills and employment opportunities. The entry of new locations as

Table VI.1. Potential implications of R&D internationalization by TNCs

	Potential benefits	Potential costs
Host country	Improved structure and performance of the NIS Contribution to human resource development (R&D employment, training, support to higher education, reverse brain drain effects) Knowledge spillovers Contributions to industrial upgrading	Downsizing of existing local R&D or losing control of technology Unfair compensation for locally developed intellectual property Crowding out in the labour market, potential harm to basic research Technology leakage Race to the bottom and unethical behaviour
Home country	Improved overall R&D efficiency Reverse technology transfers and spillovers Market expansion effects	"Hollowing out" of domestic R&D base Disappearance of certain R&D jobs Technology leakage

Source: UNCTAD.

potential hosts for mobile R&D activities also puts greater pressure on all countries to ensure that their national innovation systems (NISs) are competitive.

The implications of R&D internationalization for both host and home countries depend primarily on the extent to which it affects national innovative capabilities. The NIS approach is useful in examining the implications (Freeman 1987, Lundvall 1992b, Nelson 1993). It is based on the assumption that innovation and technology development result from complex interactions between enterprises, universities and research institutes, and government agencies. Enterprise R&D is an important, but not the only, component of the NIS: the ability of companies to innovate is intrinsically linked to the system in which they operate. Figure VI.1 provides a schematic diagramme of an NIS. In its traditional form the NIS comprises only domestic actors. However the boundary, components, and interactions between the main actors, change as R&D by FDI becomes integrated into the NIS (Liang 2004), opening up a new channel through which resources and learning can take place. If successful, this can help transform a traditional innovation (science and technology) system into one in which enterprises play a more important role. Since the TNCs that locate R&D overseas are often those engaged in high-technology activities like software, electronics and life sciences, this may also help host countries to shift into these knowledge-intensive, fast growing industries.

Different types of R&D (adaptive, innovative, technology-sourcing) have different implications for the NIS of host countries. Implications may also vary according to the *mode* through which the TNC internationalizes its R&D – whether by means of FDI (greenfield investment or acquisition), strategic alliances or subcontracting (outsourcing). Each mode creates connections to international knowledge networks, but the impacts on home and host countries differ. The impact also depends on the level of economic development of the host and home countries. There will be little or no impact on developing countries that lack the basic production and adaptive capabilities needed for new product development (chapter III). On the other hand, innovative R&D by TNCs can enable countries with some manufacturing capabilities to climb the value chain within existing industries and enter new industries. And it may help the more advanced developing countries to move from development-oriented work to applied research and eventually to basic research.

It is difficult to measure the impacts of R&D internationalization by TNCs. Conceptually, the implications for home and host countries can be examined in terms of their effects on the structure and performance of their NIS, human resources, knowledge spillovers and industrial upgrading. Broader effects (e.g. on income and, education) are also important but are beyond the scope of this report. The causal links between R&D internationalization and such aspects as productivity in home and host countries, export competitiveness and economic growth are hard to measure. The data are limited and mostly relate to developed countries. The phenomenon is still too new in developing countries to allow a full assessment, and the experience of developed countries may not offer valid insights since the drivers of R&D internationalization vary too much in the two cases (chapter V).

R&D spillovers – one of the key potential benefits – are particularly difficult to measure, and while more tangible indicators of knowledge creation or dissemination such as innovations, patents or citations exist, they are imperfect measures.[1] Finally, the counter-factual question raised in the chapter is: what are the implications of R&D internationalization by TNCs as compared with a situation in which such internationalization did not take place? This analysis does not aim to compare the implications of R&D through TNCs with those of R&D by other actors. Rather, it seeks to provide an assessment based mainly on case studies and conceptual analysis.

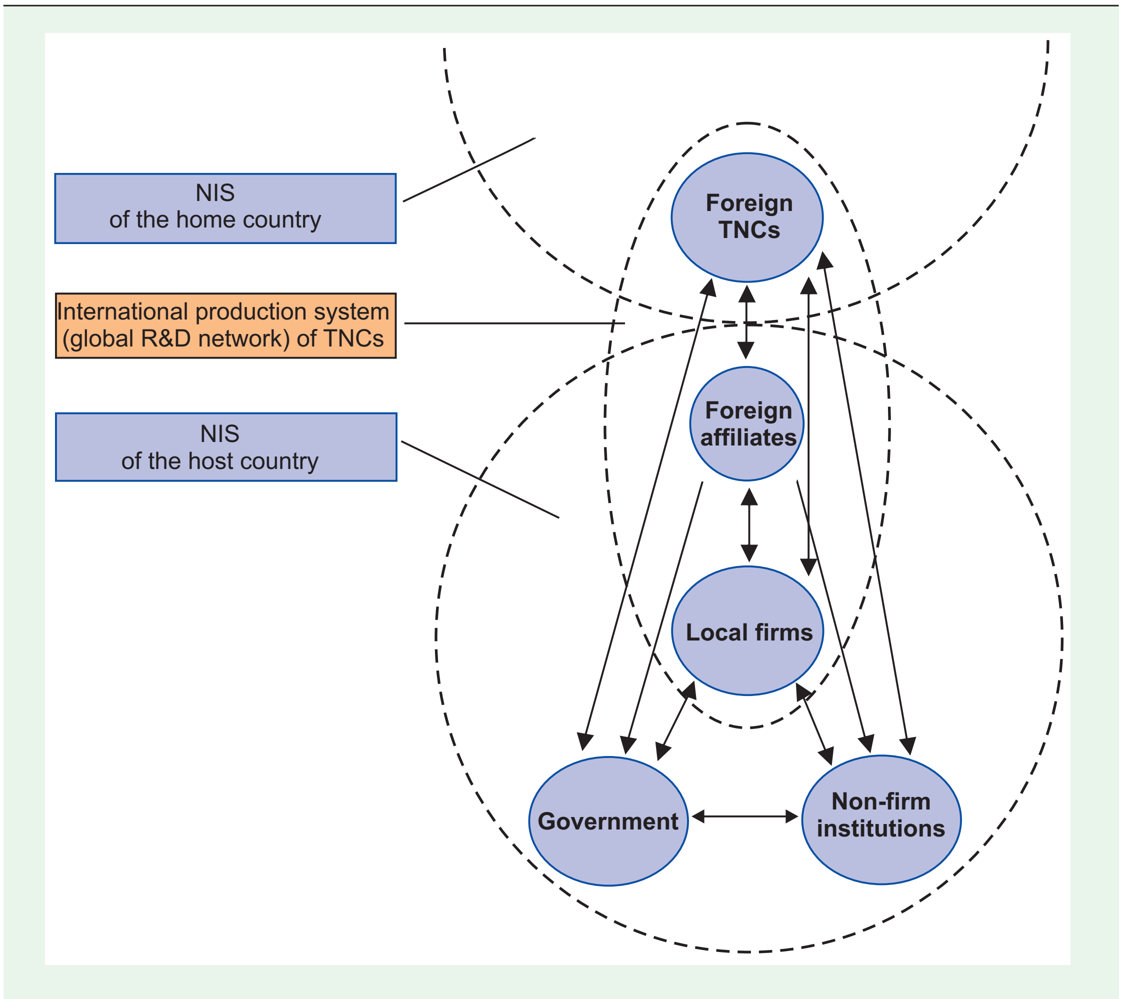
The following sections review the evidence of the impact of TNC activities in R&D internationalization. Section B considers potential host-country implications, while section C focuses on implications for home countries. Section D concludes with a discussion of the possible implications for countries that are not participating in the R&D internationalization process.

B. Implications for host countries

1. Effects on the structure and performance of an NIS

R&D-related FDI leads to structural changes in the host-country NIS (figure VI.1). Foreign affiliates conducting R&D become a part of the enterprise segment of the NIS and interact to varying degrees with local firms, science and technology (S&T) institutions and government agencies, adding to the complexity of the system.

Figure VI.1. National innovation systems and FDI in R&D: a schematic diagram



Source: UNCTAD, adapted from Liang 2004, p. 171.

They provide channels of resource-sharing between the TNCs and the host country, affecting learning and innovation in the latter. As TNCs allocate more R&D resources to the local economy, the NIS becomes increasingly linked with the global R&D network of the TNC and with corresponding innovation systems elsewhere.[2]

Enterprises are a core component of an NIS. In most developed countries they are the main innovators and the main implementers of new technologies in production. However, in developing countries, enterprises generally perform little R&D; the bulk of it is done in universities and government research institutes and is often de-linked from the productive sector. This weakens the economic impact of R&D on efficiency, growth and competitiveness.

R&D-related FDI can help overcome this absence of an innovative enterprise sector – a common weakness of developing-country innovation systems. Over time it is essential for enterprises to become lead R&D performers and for other knowledge institutions to supplement enterprise effort by undertaking basic research, applied research under contract and other technical services. TNCs bring well-developed methodologies and skills for conducting R&D. They also create demand for related services from local firms. For example, the business research culture introduced by foreign affiliates in India contributed to the development of some high-technology industries there. Texas Instruments, the first TNC to be allowed to establish a wholly owned software affiliate in India in 1986, not only inspired other TNCs to set up operations in India but also spurred the growth of the indigenous software and business services industry.[3] The influx of Texas Instruments and other foreign investors opened new job opportunities for Indian researchers in the interface between science and business.

Foreign affiliates usually maintain close technological linkages with the parent company and with sister companies. In a survey of 37 TNCs with R&D activities in India in 1995, all foreign affiliates conducting R&D (in both new and conventional technologies) had linkages with the parent firms' R&D in their home countries and 81% of R&D units in "new technologies" (mainly ICT, software and biotechnology) had linkages with parent firms' R&D worldwide (Reddy 2000). These *intra-firm linkages* are a channel through which foreign R&D resources (financial, human and knowledge) can enter a host country NIS and potentially diffuse further to other actors. These resources may be very expensive to purchase in the market – in some cases they may not be available at all.[4] Thus intra-firm linkages are potentially of great importance for the upgrading of the local innovation system.

However, the transfer of R&D resources between a parent TNC and its affiliates does not automatically lead to a diffusion of these resources within the host economy. Linkages between TNCs and domestic business entities are vital, and they only arise if the domestic firms have sufficient innovative capabilities. In economies such as the Republic of Korea and Taiwan Province of China, the upgrading from assembly to design, development and research was mainly based on domestic efforts rather than on the presence of foreign affiliates (chapter IV), although domestic enterprises and research institutes interacted with TNCs in other ways.

In other economies, the *relationships between foreign affiliates and domestic enterprises* are a core factor in the innovation system. Through such linkages, the transfer of resources can be channelled to local companies and so help improve their R&D efficiency. Some R&D activities of foreign affiliates are undertaken in direct collaboration with host-country firms. Vertical linkages related to R&D between foreign affiliates and their suppliers (*WIR01*) are particularly likely to generate spillovers because of the high degree of knowledge intensity and uncertainty of such activities. The outsourcing of R&D to local firms is another form of linkage. As R&D becomes increasingly complex, these linkages may becomes so important that they lead to the creation of formal partnership whereby the scope for learning and spillover benefits expands further. The likelihood of partnerships increases when companies have some complementary capabilities (Mowery et al. 1998, Santangelo 2000).

There are also potentially important implications from horizontal interactions between foreign affiliates and competing domestic firms. R&D by foreign affiliates adds R&D resources to host-country industrial clusters and may induce local firms to undertake more R&D to compete better. It may also show local competitors *how* to conduct R&D more effectively. The basic condition for this beneficial impact is the existence of a competitive and innovative domestic enterprise sector; this can ensure that local firms rise to the challenge posed by foreign affiliates rather than being crowded out by them (see also sections VI.B.4 and VII.D).

Foreign affiliates also *interact with knowledge institutions* such as local universities and public research institutes that undertake basic or applied research, produce R&D manpower and provide technical services to firms (chapter VII). Foreign affiliates may collaborate with these institutions (e.g. by providing financial support and conducting joint research projects) (box VI.1). Such collaboration can also benefit the R&D of other enterprises by raising the research capabilities of knowledge institutions, bringing them into contact with industrial work and promoting spin-offs.

Finally, by affecting the structure of the NIS and reallocating resources to more productive R&D, FDI in R&D may help enhance the overall efficiency of enterprise R&D in a host country. For example if the NIS initially has a strong focus on basic research, the entry of foreign affiliates conducting adaptive or innovative R&D could help activate underutilized knowledge potential (Manea 2002, Manea and Pearce 2001). R&D efficiency can also be improved if R&D by foreign affiliates is better managed, better equipped, and directed to more commercially feasible projects than that of other enterprises in an NIS. The most positive impact

Box VI.1. Collaboration between foreign affiliates and local universities: selected examples

The following are some examples of R&D collaboration between TNCs and local universities in host countries.

Microsoft Research Asia partners with academia and governments throughout the Asia Pacific region to foster innovative research, advance education and promote science and engineering. It pursues collaboration with local universities and relevant organizations through four avenues: research collaboration, curriculum innovation, talent fostering and science exchange. In research collaboration it has established joint research labs at Tsinghua University, Zhejiang University, Harbin Institute of Technology, Hong Kong University of Science and Technology and University of Science and Technology of China to cooperate with Asian academia. It conducts theme-based project funding to help research in specific areas.

Intel had more than 250 sponsored research projects under way at various international universities in early 2005. Its teacher training programme, launched in 2000, has offered training to more than 2 million classroom teachers in 30 countries, and the company collaborates with ministries of education or other government entities to adapt the curriculum in some countries.

Seagate Technology in Thailand cooperated with Khon Kaen University to open the Khon Kaen-Seagate Cooperation Research Laboratory for applied R&D in recording-head manufacturing technology. The lab uses system level technology and a systems research approach to broaden students' knowledge and expertise. The lab will also be a shared resource for both Seagate staff and students of Khon Kaen University who will be working together on projects. Cooperation between the industrial sector and universities offers opportunities to develop further and drive future growth in the hard disk drive and other related industries in Thailand.

In Brazil, the University of Campinas in Sao Paulo collaborates with a number of foreign affiliates in R&D. More than 250 partnership agreements with private companies and 60 agreements with public companies have been established at the university to date. Among participating foreign affiliates are *Ericsson* for the development of technology of fibreglass for optical amplifiers and *Motorola* for the development of professional capabilities in electronics-related areas. Other agreements involve foreign affiliates of *Aventis*, *Bayer*, *Compaq*, *Hewlett-Packard*, *IBM*, *Monsanto*, *Novartis*, *Roche* and *Tetra Pak* (UNCTAD forthcoming e).

In Rabat, Morocco, *STMicroelectronics* has established a training centre to train teachers and students from engineering schools and to provide a syllabus that will help them contribute to innovation activities in the semi-conductor industry.

Source: UNCTAD, based on company information.

on the NIS structure and efficiency may be achieved if the foreign affiliates initiate projects that would otherwise not have been carried out but that contribute to enhancing the specific strengths of the local NIS (Pearce 2004). However, such benefits are not automatic; local innovative capacities are among the most important determinants of their extent and diffusion. The ability to make commercial use of results generated through R&D in a host country depends on factors that can be influenced by government actions (chapter VII).

2. Human resource implications

While a good supply of highly skilled human resources can attract FDI in R&D (chapter V), FDI in R&D can also help in the development of such resources. TNCs generally have the most advanced capabilities for conducting R&D, and their affiliates can make significant contributions by transferring people with the necessary skills and methodologies to host countries. In addition, they can play a part in strengthening local human resources through in-house training, supporting local education and collaborating with local universities. They can also facilitate a "reverse brain drain" by attracting back skilled nationals working abroad.

Increased R&D employment. R&D employment by foreign affiliates is growing fast. For example, majority-owned foreign affiliates of United States companies increased their R&D staff by more than one-fifth during the period 1994-1999 (chapter IV). Most of these jobs were created in developed rather than developing countries, but the rate of growth in the latter has been even higher especially since 1999. There was a rapid increase in R&D employment in foreign affiliates, e.g., in China, the Czech Republic, India and Singapore, and recent survey data on FDI projects and TNC strategies suggest there will be further increases (chapter IV).

In China, for example, Motorola established the first foreign-invested R&D centre in 1990 and has so far hired a total of 1,300 engineers (box IV.6). Philips has some 700 R&D staff, which is set to increase to 1,300 over the next two years. GE's new global research centre in China was formally opened in 2003, hiring 500 researchers; it is expected to employ 1,200 by 2005.[5] There are similar figures in India, where, for instance, GE's global research centre in Bangalore employs around 2,400 people.[6] High levels of education are generally required for these jobs. For instance, in GE's laboratory in China, more than 80% of the engineers hold PhD degrees, and in Bangalore 60% of the employees have post-graduate qualifications in science. Also, foreign affiliates often offer better employment conditions: higher salaries, better working facilities and more sophisticated training (Zhang 2005).

Training. Many TNCs provide in-house training to their employees. Training undertaken by foreign affiliates conducting R&D can help develop new and advanced skills among local engineers and researchers. The types of training may range from on-the-job training to seminars and overseas training, including at the parent company. For example, almost all the 250 engineers and researchers recruited locally in Thailand at the Toyota Technical Centre Asia Pacific (Thailand) (box IV.7) had been sent to Japan for training. In some host countries the government has invited leading TNCs to help set up and run joint or cooperative training centres (chapter VII).

Supporting higher education. Some TNCs that undertake R&D in developing countries to tap pools of low-cost technical manpower support local universities and engage in curriculum development and talent fostering. They may help increase or upgrade training in specific skills. Others provide internship and fellowship programmes to high-performing students. Their research collaboration with local universities can offer a means of supporting higher education while simultaneously diffusing knowledge (section VI.B.3; box VI.1). However, host countries should ensure that national school and university curricula do not become overly directed towards the needs of particular firms. The potential contributions by TNCs should be balanced against the risk of becoming too "asset-specific" in their R&D and education focus.

Human resource spillovers. Spillovers take place when trained employees move to other firms or set up their own businesses. This is well documented from TNCs' production activities, such as in the electronics industry in Malaysia (Hobday 1995). Spillovers from R&D activity have not been analysed separately but are likely to be similar. Research personnel trained in leading TNC affiliates are bound to be highly prized by local firms seeking to launch R&D. These effects on human resource development may be greater when

R&D by TNCs is linked to local production than when it is conducted as a separate activity. For example, in India the main beneficiaries of electronics R&D by TNCs are probably the engineers directly engaged in research, whereas in China, where R&D is more often linked to production, larger spillovers may benefit local producers and exporters.

Brain-drain effects. In some developing countries the appearance of new career opportunities in foreign affiliates (and domestic firms that perform contractual R&D for TNCs) is contributing to a "reverse brain drain". Many scientists, engineers and entrepreneurs who moved abroad to work in universities, R&D institutions and TNC labs are returning home to such countries as China and India. The returning diaspora often bring back knowledge of new research techniques and large-scale research management skills, in addition to their scientific knowledge. Some retain links with the firms or institutions abroad for which they worked: some become local managers of foreign affiliates or set up their own enterprises with contracts from abroad. This has happened in Brazil, China, India, the Republic of Korea, Singapore and Taiwan Province of China as well as in developed countries such as Ireland. For example, Zhongguancun Science Park in Beijing hosts 2,500 companies established by those returning from abroad (box VI.2). In Taiwan Province of China, many companies were established by people who had worked abroad for TNCs (Lin and Rasiah 2003).

The "reverse brain drain" may prove to be one of the most significant benefits of R&D internationalization. However, this benefit will accrue only to developing countries that have the skills, infrastructure and other requirements needed to attract R&D. It may be more difficult for other countries to encourage their best technical graduates to give up jobs in more advanced countries and return home (chapter VII).

3. Knowledge spillovers from R&D by TNCs

Given the nature of knowledge as a public good, it can be expected that the R&D activities of a foreign affiliate will generate some spillover benefits to other firms and institutions in a host economy. R&D activity builds upon the stock of knowledge, both explicit and tacit, in an enterprise. Some of the knowledge that TNC R&D creates may only benefit the TNC itself (if it is protected by patents or is so specialized that it cannot be transferred). However, some knowledge can "leak" out to and benefit the

Box VI.2. Reverse brain drain: the case of the Zhongguancun Science Park in Beijing

Zhongguancun Science Park, China's first and largest science park and home to 40 universities and 130 research institutes, has attracted foreign as well as domestic R&D centres. By 2004, 41 foreign-invested R&D centres had been established by such leading TNCs as Hewlett-Packard, IBM, Intel, LG, Lucent, Microsoft, Motorola, Nokia, Nortel, Oracle, Samsung, Siemens, Sony, Sun Microsystems and Toshiba.

Returning members of the Chinese diaspora play an important role in these R&D centres. Some TNCs have appointed Chinese researchers who previously worked at their headquarters as heads or chief scientists of their R&D centres in Beijing. This has contributed to attracting back top Chinese scientists in specific areas, at least temporarily. For example, three consecutive directors of *Microsoft Research Asia* (box VI.1) were highly qualified Chinese scientists in computer science working with Microsoft in the United States. Although locally recruited researchers provide the main manpower for the activities of foreign-invested R&D centres, expatriate staff, particularly overseas Chinese, are a valuable complement with their knowledge and experience from working abroad. When some returning diaspora leave foreign affiliates and join local research entities or establish their own companies, they contribute further to the enhancement of local innovative capability.

For some returnees who decide to establish their own businesses, these foreign-invested R&D centres may also become important customers. In fact, out of the 14,000 high-technology firms located in the Park, 2,500 companies have been established by graduates returning from abroad.

Source: UNCTAD.

wider research community of a host country. With the establishment of foreign-invested R&D centres, tacit knowledge can be accessible locally to domestic entities.[7] Spillovers of tacit knowledge may be particularly valuable for a host country. Tacit knowledge plays a critical role in R&D but is difficult and costly to create locally.

There may be some tension between the interests of the host country and that of the TNC with regard to knowledge spillovers. While the former would seek to maximize the knowledge diffusion to other firms in the economy, the TNC often may want to minimize "leakages". Many compromises are possible (after all, the situation is very similar in the home country of the TNC). IPR protection can limit the loss to the firm, as can other strategies to limit the cost of spillovers (box VI.3).

Box VI.3. Protecting against the risks of technology leakage

While host countries see inward FDI as a means of building technological capabilities, TNCs are often reluctant to transfer technology or engage in local technological activity that may help local firms to become competitors. TNCs therefore try to limit the ability of local competitors to appropriate their proprietary technology by various means (box table VI.3.1).

TNCs may insist on *full ownership* of their affiliates, thus limiting access to knowledge by local firms that could otherwise be joint-venture partners. While local companies can still poach employees from foreign affiliates, their access to knowledge is likely to be more limited than if they were able to share ownership and thereby have their own people working on all activities in the foreign affiliates.

TNCs generally protect their *core competencies (technologies)* more than their non-core competencies, and are more willing to transfer the latter to foreign affiliates, outsource them or develop them in collaboration with local partners. This need not mean that non-core technologies are obsolete or of low value to the host country; they may be new and valuable but peripheral to the TNCs' core activities.

TNCs may transfer some core technology to foreign affiliates, which then work to improve their production through local process R&D. They may protect against its appropriation by *making the outcome and production dependent on the parent firm*, such as through local engagement in component production that has little value except if combined with other components that the TNC produces elsewhere. TNCs may decide to develop new technologies using a system of multiple locations in which no foreign affiliate has access to the full technological system.

TNCs may also transfer technology tacitly rather than explicitly, thus slowing its absorption by local employees and its re-transfer to a local partner. This gives the TNC more time to develop new competencies while slowing the affiliates' development of their own R&D capabilities.

Box table VI.3.1. Actions by TNCs to limit risk of spillovers in a host country

Action	Potential effect
Enter with wholly-owned operations	Reduces monitoring costs and risk of loss because of difficulty for outside companies to become sufficiently knowledgeable about the technology in order to appropriate it.
Transfer non-core technology of low value to transferer	Lower costs of loss to transferer from misappropriation, but transferees may be satisfied because of the asymmetrical value of the technology.
Transfer core (high value) but dependent (incomplete) technology	If appropriated, the value is low for the transferee because the technology can only be used in conjunction with complementary technologies held by the transferer.
Transfer technology in tacit rather than explicit form	Even if employees within the affiliate understand the technology, their transfer to another organization is slow because they must transfer it tacitly as well.

Source: UNCTAD, based on Cannice et al. 2003, 2004.

Knowledge spillovers can take place primarily through the mobility of labour, enterprise spin-offs and demonstration effects. If foreign affiliates are "embedded" in the host country NIS, with close interaction between foreign affiliates, domestic firms, universities and research institutions, the scope for spillovers increases (section VI.B.1).

As mentioned above, employee turnover is one of the principal ways in which technology and knowledge spill over to the domestic economy. This can be particularly valuable in developing countries, as this diffuses skills and experience that are difficult to gain in other ways. It is particularly significant for R&D, since tacit knowledge is embedded in the knowledge and experience of individuals rather than in hardware or capital equipment. The extent of such diffusion depends on whether domestic firms are as attractive employers as foreign ones. In developing countries, foreign affiliates often offer better salaries than local competitors.[8]

Local firms or institutions can, of course, improve their attractiveness. For example, a research director of a TNC R&D centre in China recruited a whole team of researchers back to the Chinese Academy of Science, in part by offering them the opportunity of doing independent research. "Examples of individual senior researchers leaving TNC R&D centres to join local companies are numerous, and it will continue to occur over the years" (Chen 2004, p. 37). In Malaysia, engineers who worked in local affiliates of TNCs like Motorola, Texas Instruments or Intel subsequently moved to R&D management jobs in local firms (Rasiah 1996).

Another channel for spillovers are "spin-off" firms or innovations from foreign affiliates. China Techfaith Wireless, China's largest independent R&D company for the design of mobile phones, was formed by a 14-person team that left Motorola China in July 2002. The spin-off was later listed in NASDAQ in May 2005.[9] Photonic Bridge, another R&D firm in China, was founded by a team of engineers and researchers from Lucent.

Knowledge spillovers are inherently difficult to measure. The few existing studies are based mainly on data related to R&D by foreign affiliates in developed countries. Studies based on patents citation data suggest that R&D spillover also takes place from foreign affiliates to local firms in the United States (Almeida 1996, Branstetter 2000).[10] Similarly, another study found that foreign R&D had a significant positive effect on domestic innovation in 147 geographic subregions of Europe, Canada and the United States (Peri 2004).

According to one study, R&D by foreign affiliates in Singapore has acted as "a window through which local Singaporean inventors tap into a much larger knowledge pool" (Hu 2004, p. 798). Inventors in Singapore relied more on patents from TNCs with a presence there than did inventors in other countries. This difference was particularly marked in computers and communications industries as well as in electrical and electronics industries – industries in which foreign affiliates play an important role in Singapore (Hu 2004).

Studies conducted in the EU under the Community Innovation Survey programme, however, do not provide strong evidence of spillovers from R&D by foreign affiliates. A survey of Belgian foreign and domestic R&D firms in manufacturing found no significant technology transfers from TNCs to the local economy (Veugelers and Cassiman 2004). While foreign affiliates in the survey were more likely than domestic firms to describe themselves as "innovative", acquire technology internationally and cooperate in R&D with local firms, they were less likely to be "locally networked" and to transfer technology to the local economy.[11] A similar picture emerged in France, where foreign affiliates used fewer local sources and cooperated less with local partners than did domestic firms (Sachwald 2004b). In Italy, foreign affiliates with asset-seeking innovation strategies were found to interact more with local firms and institutions than those with adaptive R&D strategies (Balcet and Evangelista 2005, box VI.4). A study of the productivity effects of inward and outward FDI in Swedish manufacturing found no evidence of R&D spillovers at the firm or industry level (Braconier et al. 2000).

Apart from paucity of data and methodological problems that might explain the apparent lack of evidence of spillovers, it has been suggested that spillovers between countries that are already technological leaders may in fact be limited (Braconier et al. 2000, p. 18). Indeed, a recent study confirms that the impact of inward FDI in R&D on innovation and productivity varies by the level of development of the host economy (AlAzzawi 2004). In newly industrializing economies, inward-FDI-induced R&D spillovers weighted by patent citations had potentially a strong positive effect on local innovation and productivity, especially if the FDI came from technologically leading countries. In developed countries on the other hand, inward-FDI-related R&D negatively affected local innovation but still had positive effects on domestic productivity (AlAzzawi 2004, p. 28): "FDI-induced R&D spillovers can be very important for less advanced economies. This is true both if innovation or productivity is our variable of interest. It seems that the further apart the source and recipient are in terms of level of technological advancement, the larger the

Box VI.4. Asset-seeking foreign affiliates create more local R&D linkages: the case of Italy

Foreign affiliates accounted for about 33% of all business enterprise R&D in Italy in 2001 (annex table A.IV.1). Their levels of interaction within the local NIS differs considerably according to their strategies — notably whether they seek to penetrate the Italian market based on imported technologies or to exploit local technological and human resources. Drawing on data from the third Community Innovation Survey for the period 1998-2000, a recent study assessed the technological contribution of foreign affiliates and their innovative activities (Balcet and Evangelista 2005).

A simple comparison with domestic firms suggests that foreign affiliates have a relatively high propensity to innovate, that they devote more resources to innovation and R&D activities, cooperate more with other firms and institutions, and establish formal technological linkages with other firms within the enterprise group to which they belong. However, much of this is explained by the fact that foreign affiliates are overrepresented in science-based and scale-intensive industries; it is also explained by their greater size. In fact when controlling for these factors, the propensity to innovate was lower in foreign affiliates. Affiliates did show a relatively high propensity to introduce new product innovations, to patent and to spend more on R&D. Meanwhile, external linkages with universities and R&D centres were less frequent and important for affiliates than for domestic firms.

Out of 535 manufacturing foreign affiliates contained in the Italian data-set, low-technology affiliates (which basically import the technology they need from abroad) and foreign affiliates with no innovative activities whatsoever accounted for 42% of the sample. Among the remaining 312 firms, most affiliates applied *adaptive* R&D and innovation strategies, mainly targeting the domestic market. There is thus a heavy concentration of adaptive, low-technology and non-innovative strategies among foreign affiliates in Italy.

In general, "adaptive affiliates" displayed weak external linkages, often involving intra-group technology transfers from headquarters. Local sources of knowledge such as universities and R&D centres were generally not perceived as important. Innovation (and also R&D) efforts of these affiliates were incremental and adaptive in nature. All types of industries were represented in this cluster in Italy.

About 50 affiliates were characterized as "asset-seeking". They had a higher level and scope of technological interactions with the external environment. Innovation activities were mostly undertaken in cooperation with other firms and institutions, such as universities and R&D centres. The most innovative *asset-seeking* affiliates had a strong internal commitment to innovation and R&D. The other *asset-seeking* affiliates depended more on knowledge, competencies and expertise absorbed from the external technological and scientific environment. The first type was strongly represented in science-based industries, whereas the industry composition of the other asset-seeking group was very mixed. Asset-seeking behaviour was found not only in science-based but also in medium-technology industries as well as in specific technological niches where Italian firms hold a comparative advantage. Such industries include mechanical engineering, home appliances and traditional industries like textiles and footwear.

The Italian case thus suggests that an "asset-seeking" pattern of internationalization can be pursued by different types of foreign affiliates, as long as the host country has accumulated a sufficient stock of sharable knowledge.

Source: UNCTAD, based on Balcet and Evangelista 2005.

potential positive spillover from knowledge flows on the recipient."

The experience of Italy (box VI.4) and the Czech Republic suggests that the situation may differ by industry. In the Czech automobile industry, for instance, TNCs helped create a sophisticated innovation system because of their long-term commitment to upgrading their R&D capabilities, patenting as well as cooperation with universities and R&D labs (Srholec 2005b).[12] The R&D intensity of both foreign and domestic firms in this industry was well above the national average, reaching levels similar to those of other automobile producing countries like France, Germany, Japan, Sweden and the United States. By contrast, TNCs in the Czech electronics industry largely undertook contract manufacturing, and invested little in R&D. The R&D intensity of foreign affiliates was substantially lower than that of domestic firms and below the average for manufacturing. For the economy as a whole, foreign ownership was found to have a significant *negative* impact on the propensity to conduct R&D (Srholec 2005b).[13] As in the other studies noted above, foreign affiliates were more likely to cooperate with non-affiliated firms abroad but less likely to cooperate with domestic firms and institutions.

4. Contributions to industrial upgrading

The internationalization of R&D may help host countries move up the value chain and enhance competitiveness. Industrial competitiveness involves four interrelated types of upgrading: *process upgrading*, *product upgrading*, *functional upgrading* (new mix of activities or different activities in the value chain) and *chain upgrading* (moving to a new value chain in products of higher technology intensity) (Kaplinsky and Morris 2001). Industrial upgrading usually follows the sequence from process upgrading through product upgrading and functional upgrading to chain upgrading (Gereffi 1999, Lee and Chen 2000).[14] R&D by TNCs can contribute to all four. The extent to which it contributes to *process* and *product upgrading* in host-country industries depends on where the results of the R&D are applied. Adaptive R&D and some innovative R&D directed towards the domestic market may contribute directly to process and product upgrading in domestic industry, while the impact of innovative R&D for global markets is likely to be more indirect.[15] For developing countries with relatively low levels of innovative capabilities, product and process upgrading of industries may be particularly important.

R&D by TNCs may lead to *functional upgrading* in domestic industries: from assembly work to R&D, design and other knowledge-based activities. Countries specializing in labour-intensive assembly are vulnerable to competition from countries with lower wages.[16] Economic rents in the value chain are increasingly to be found in areas outside production, such as R&D, branding and marketing. But developing countries that seek to move up along the value chain to R&D functions and other knowledge-based activities often encounter bottlenecks such as a lack of resources and local demand for these activities. By transferring resources to a host country, providing demand for R&D outcomes and stimulating the business innovation culture (sections VI.B.1 and VI.B.3), TNCs may help developing countries upgrade functionally towards higher value-added activities.

R&D by TNCs may contribute to *chain upgrading*, from simple value chains to those for products involving more advanced technologies. Traditionally, low-income developing countries were considered to have a comparative advantage only in low-technology industries. The emergence of a developing country as a destination for the global or regional R&D centres of TNCs can change the public perception of that country and help attract FDI in other knowledge-based activities as well. Indeed, countries that have begun to attract innovative R&D by TNCs may already benefit from "reputation effects" as more companies start considering them for future R&D expansion. Some developing countries have successfully built up more knowledge-intensive industries by leveraging R&D by TNCs. In China, for example, R&D by TNCs (box IV.8) and by domestic companies (such as Huawei and ZTE) have contributed significantly to the rapid upgrading of the Chinese telecom equipment industry – from central office switches to mobile telecommunications and other high-end equipment (Liang 2004). In Singapore, R&D by TNCs was a key factor in creating an innovation and industrial cluster around biomedical sciences such as pharmaceuticals and biotechnology (box VI.5). Rather than remaining as exclusively low-cost manufacturing locations, these two countries have leveraged their relatively well-educated populations and better innovation infrastructure to become centres of excellence for innovation.

R&D by TNCs can also contribute to the formation of industrial clusters at the regional level of a country. In the Pudong New District in Shanghai, for example, a complete value chain has emerged since 2000, partly as a result of FDI inflows. By 2003 some 25 specialized chip design companies, four contract manufacturers, 14 package and test companies, 22 equipment suppliers and some training and technical service providers were present in the area.[17] As of early 2005, there were 129 chip design companies in Shanghai employing 5,000 engineers and researchers.[18] Over time the cluster has made significant technological leaps in the area of integrated circuits and moved up the value chain,[19] and in 2004 sales of integrated circuits increased to above $2.4 billion, accounting for one-third of the national total. Government policies at the local level significantly assisted this process (section VII.D).

5. Potential concerns related to R&D internationalization

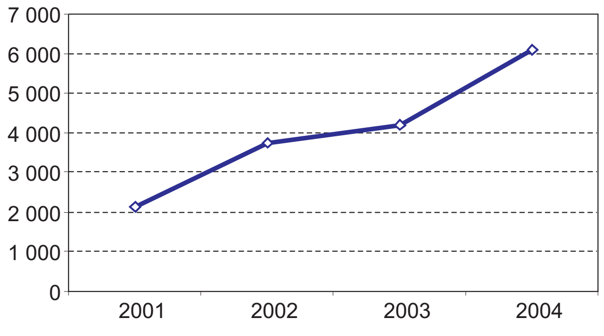
The potential costs of R&D internationalization for host countries depend on the type of R&D and its motive, the mode of TNC entry to conduct R&D and the strength of the host country's innovation system. The main concerns relate to the potential downsizing of R&D following cross-border M&As, unfair sharing of intellectual property resulting from local R&D, crowding out of local firms from the market for researchers, possible negative impacts of R&D fragmentation, a race to the bottom in attracting R&D-related FDI and unethical behaviour by TNCs (table VI.1). These are taken in turn below.

Box VI.5. R&D by TNCs in the biomedical science industry in Singapore

In the "Industry 21 Vision", a blueprint for Singapore's economic strategy in the 21st century, the biomedical sciences industry was identified as a key growth engine for the country.[a] Since this initiative was launched in June 2000, Singapore has demonstrated rapid progress in the upgrading of this industry within a relatively short time span. Based on both domestic efforts and FDI by TNCs, Singapore has built world-class capabilities across the entire value chain, from R&D to manufacturing in biomedical sciences and headquarters' services in the biomedical sciences industry. In manufacturing the overall output of the industry grew to $9.6 billion in 2004. The total value added of manufacturing in biomedical sciences was $6.1 billion (box figure VI.5.1), accounting for 21% of the country's total value added. Meanwhile, Singapore has successfully obtained patents and developed new products in the biomedical sciences.

TNCs have contributed to the biomedical sciences cluster in Singapore. They have played an important role in industrial upgrading through their R&D activities, ranging from basic research to clinical development. Pharmaceutical companies like Eli Lilly, Isis Pharmaceutical, Vanda Pharmaceuticals and Paradigm Therapeutics all conduct R&D in Singapore. Medical technology companies with an R&D presence include BD, Welch Allyn, Essilor, Siemens Medical Instruments, Bracco, Applied Biosystems and Fischer Scientific.

Box figure VI.5.1. Value-added of the biomedical sciences industry in Singapore
(Millions of dollars)



Source: EDB Singapore.

Source: UNCTAD, based on ISPE 2003 and information from Economic Development Board, Singapore.

[a] This covers biomedical sciences, pharmaceuticals and medical technology.
[b] For example, Eli Lilly invests $140 million in R&D and employs over 50 scientists and researchers.

Downsizing of existing R&D capacity and losing control of technology. The internationalization of R&D is partly the result of TNCs acquiring companies that perform R&D.[20] Such acquisitions may lead to a reduction of R&D activity as part of rationalization programmes. Similarly, strategic R&D activities may be relocated as a result of a takeover; this is of particular concern to technology leaders but it may also affect some developing countries or transitional economies that have special technological strengths.

A relevant factor here is whether acquiring and acquired firms are technologically complementary or competitive. For instance, a study of 62 firms in the EU found that there was a reduction in R&D activity after a merger when R&D activities were competitive (Cassiman et al. 2004). The remaining R&D became narrower in scope (or more focused) and its time horizon became shorter. Key employees tended to leave more often. These effects were stronger when the companies had been rivals before the merger.

In Latin America, R&D has rarely been the main reason for TNC entry, although many acquired State-owned and private enterprises were R&D performers. In many cases, R&D was subsequently downsized or closed entirely in a move to concentrate R&D activities at headquarters or elsewhere within the TNC network (Velho 2004, Cimoli 2001). In the automotive and pharmaceuticals industries in Brazil and Argentina, some TNCs downsized R&D but increased production (Velho 2004, Cimoli and Katz 2001). But not all takeovers have had the same outcomes. Two takeovers in the auto parts industry in Brazil are illustrative. When the domestic producer of shock absorbers, Cofap, was acquired by Magnetti Marelli (Italy) in the 1990s, the R&D team was maintained, mainly because of their high level of technological competence. Conversely, in the acquisition by Lucas Varity (United Kingdom) of Freios Varga, a brakes producer, the R&D was dismantled despite the competence that had been accumulated in the local firm. As an explanation for these diverse results, it has been proposed that brakes may require less local adaptation than shock absorbers (Costa 2005). Some companies – including Ford (United States), Volkswagen (Germany) and Alcatel (France) — have reversed previous decisions to close local R&D in order to boost their competitive position in the Brazilian market (Queiroz et al., 2003; Costa 2005). In China also there are concerns relating to the closure of R&D units in local firms that have entered into joint ventures with foreign firms.[21]

In Central and Eastern Europe, many companies were taken over by foreign TNCs as part of privatization programmes. An UNCTAD survey in 1999 covering 23 major privatized companies found that the average annual growth of R&D expenditure fell from 23% to 14% after privatization, and R&D intensity (R&D expenditure as a percentage of sales) diminished significantly (Kalotay and Hunya 2000).[22] It is possible that R&D expenditures were boosted before privatization to show better company performance before the sale, or that they were the continuation of previous non-market-oriented and overstaffed programmes (ibid., p. 55). In one prominent case, R&D activities were continued and expanded: GE's purchase of Tungsram in Hungary initially involved layoffs but later led to the company becoming GE's centre for lighting activities throughout the world, including R&D (ibid., p. 51).

The risks of R&D closure are likely to be smaller when FDI is undertaken to reap cost advantages from conducting R&D abroad or to access local technical skills and markets. Closures do not appear to have occurred to a high extent in R&D labs in developed countries such as the United Kingdom (Griffith et al. 2004). Similarly, a study of 35 companies privatized in eight European countries found that while R&D intensity decreased, R&D outputs (measured by the number and quality of patents) increased (Munari and Sobrero 2005). There have been several cases in the Canadian chemicals industry of TNCs reducing or closing local R&D after acquisition; Shell closed its R&D capacity in Oakville, and Diversey moved its R&D to Chicago (Rugman and D'Cruz 2003). However, there are also examples of R&D expansion: the Canadian affiliate of Uniroyal Chemical (United States) retained a key role in the parent company's global R&D, partly because of its high technical capacity.[23]

Unfair compensation for locally developed intellectual property. There may be concerns that local firms, universities or research institutes collaborating with TNCs on R&D do not receive fair compensation for intellectual property developed locally, either before or after partnering with TNCs. Due to unbalanced bargaining power, information asymmetry, market failures or institutional deficits, the contractual arrangements between TNCs and their local counterparts may not reflect a fair allocation of rights and responsibilities, to the disadvantage of local entities. This can lead either to unfair pricing of R&D inputs or to a biased allocation of ownership of the R&D outputs. Both issues are closely related to IPRs.

The ownership of intellectual property determines subsequent revenue flows in the form of patent fees or new product sales. On the one hand, host developing countries may fail to reap the long-term financial benefits of FDI in R&D when they do not have a fair share of ownership of, and related economic rents from, the resulting intellectual property. Lack of ownership of intellectual properties may also make a developing country dependent on TNCs for its technological progress. Moreover, a patent can be framed to cover intellectual property developed by local research partners even prior to collaboration with a TNC. This could be fair if the local partner has given its consent and is appropriately compensated. However, the legal implications of IPR protection may not be fully appreciated by firms and universities in developing countries. If unaccustomed to patenting they may find it difficult to strike an appropriate deal with their foreign R&D partners, particularly in host countries that lack an effective IPR system.[24] The main approach to address these concerns is to strengthen relevant domestic institutions (section VII.B) and the ability of domestic firms and R&D institutions to manage IPRs effectively.

Crowding out in the labour market and potential harm to basic research. When foreign affiliates enter a host location there may be concerns about local research entities finding it more difficult to attract or retain the best R&D staff, thus hampering their ability to innovate.[25] In China, for example, some observers have noticed a tendency for talented researchers to leave domestic companies and government labs to take up a career path in foreign affiliates' R&D units (Simon 2005, p. 12). Even if the NIS as a whole would benefit, it may represent an opportunity cost for individual local entities (research institutes, universities and enterprises). If the reallocation of human resources harms the manpower supply for basic research, the long-term efficiency of an NIS may also be negatively affected. Ultimately, what matters is the trade-off between the contributions of TNCs to the strengthening of the NIS on the one hand, and the loss of skilled personnel to local R&D, which may or may not lead to a stronger NIS as a whole. The evidence on this is scanty, and it is not easy to assess the net impact.

Possible negative impact of fragmentation of R&D by TNCs. TNCs increasingly divide their R&D activities into modules, allocating different tasks to different countries. Some may confine their R&D activities in developing host countries to low levels of skills or technology to protect valuable proprietary technology. This can deprive host countries of learning opportunities and reduce the spillover benefits. In Brazil, for example, there is concern that the fragmentation of R&D is leading to a downgrading of human capital in car production (Posthuma 2000). It has also been argued that fragmentation may bypass the development sequence and limit the extent of real roots within the local NIS, making the R&D activity rather footloose (Pearce 2004). On the other hand, fragmentation may enable more countries to participate in global R&D by TNCs. Moreover, economies of scale in research specialization could produce greater employment in research and attract R&D by other TNCs if the country develops a good reputation for efficient research.

Race to the bottom and unethical behaviour. As competition for FDI intensifies there is a risk that governments will compete in offering over-generous incentives to attract FDI. This could lead to losses in tax revenue or the lowering of regulatory standards (with associated damage to the environment or workers' welfare). One concern in this context is that TNCs tend to locate R&D in developing countries to take advantage of their relatively lax employment or social protection policies. In the pharmaceuticals industry, this could lead to the flouting of ethical or medical standards found in developed countries. TNCs may be tempted to conduct clinical trials on new drugs in developing countries where "the costs of conducting the trials are lower and human subjects can be recruited more easily."[26] The issue here may be one of poor regulatory frameworks in host countries or it may be chronic unemployment and poverty that make clinical subjects willing to take health risks that would be unacceptable in developed countries.[27]

Meanwhile, there has been progress in the international harmonization of standards for clinical trials. TNCs, which depend mainly on

Box VI.6. Clinical trials in India

Clinical trials – the approval process for new pharmaceutical products – are time-consuming, expensive and ethically difficult. They involve recruiting hundreds, often thousands, of people to volunteer for the testing of new medicines. India is an increasingly attractive destination for clinical research for pharmaceuticals groups looking for faster and more efficient ways to test drugs for western consumers.

India is well endowed with skilled R&D personnel. It also has a relative abundance of people with diseases that exist in developed countries (including up to 30 million people with heart disease, 25 million with type-II diabetes and 10 million with psychiatric disorders). This includes a large pool of what are called "treatment naive" patients who have not yet been exposed to other drugs on the market. In addition, Indian recruits are more likely to comply fully with the trial process, unlike in developed countries where a significant proportion of subjects drop out in order to seek second opinions.

It has been estimated that firms can reduce costs by 20-30% by moving these R&D activities to India. Savings come from hiring clinical researchers, nurses and IT staff at less than a third of wages in the West, in addition to differences in the costs associated with the patients. Reflecting this, it is estimated that the number of clinical research organizations based in India increased fourfold between 2001 and 2003. Indian firms, too, are participating in this new industrial activity.

One factor apparently underpinning the shift has been India's newly adopted guidelines on "good clinical practices", including the issue of "consent by the patients" in line with global norms. However, other commentators have questioned what "consent" can mean in a drug trial when patients are illiterate and might not adequately understand the experiment's true risks; by definition, the drugs being tested have unknown beneficial effects on the patient's illness or disease, and negative side effects are also unknown.

There are some factors holding back the development of clinical research in India, such as relatively slow approval processes. Another one is India's reverence for animals, which makes it difficult to use certain animals (like monkeys).

Source: "Evidence regarding R&D investments in innovative and non-innovative medicines", *Financial Times*, 14 October 2003; Love 2003, "Eastern rebirth of the life sciences", *Financial Times*, 10 June 2005.

developed-country markets for profits, increasingly have to carry out multi-centre and multi-ethnic clinical trials under the internationally agreed standards (box VI.6).

C. Implications for home countries

The home countries of TNCs also face benefits and costs when their firms expand R&D abroad. The benefits are that R&D abroad may lead to reverse technology transfers, lower costs and therefore increased R&D, leading to improved competitiveness of the TNCs (which can also benefit other firms in the home country). The costs are that R&D internationalization may lead to a "hollowing-out" of domestic innovation, lost research jobs and leakage of valuable proprietary technologies. The net outcome is difficult to predict. It depends on a range of factors: the motives for R&D internationalization, the degree to which the TNC is integrated in the NIS of home and host countries, and the levels of development of home and host countries.

1. Improved overall R&D efficiency

As R&D grows more complex, it tends to use a more diverse set of information, skills and knowledge. This set may not be available within a single firm, or even a technology leader, or within a single country. Where this is so, R&D internationalization may be necessary in order to conduct R&D efficiently by tapping a broader range of resources. The availability of research manpower or of a knowledge base abroad can accelerate new product development. Lower costs in developing countries can make R&D more economical. All these advantages to TNCs potentially feed into the technological performance of their home countries, and thus to their competitiveness and growth.

The efficiency gains for a TNC from tapping into the competitively priced pools of talent in Asia can be substantial. For example, a three-month, pre-clinical toxicology study on one compound might cost $850,000 in the United States but only $100,000 in India.[28] Similarly, the collaboration between PalmOne (United States) and HTC (Taiwan Province of China) on the Treo 650 smartphone helped reduce the development time of the product by several months while decreasing the number of defects by 50% (Engardio et al. 2005).

The internationalization of R&D can also allow home countries to retain and focus more on higher value added activities, offshoring less sophisticated or non-core innovative activities to developing countries (Reddy 2000). In the PalmOne case, resources in the United States were focused on software while the hardware development was shifted to HTC in Taiwan Province of China.[29]

2. Reverse technology transfer implications

An important potential benefit to the home country from R&D internationalization is reverse transfer of technology, whereby knowledge acquired by foreign affiliates through R&D (in-house, outsourced or collaborative) is channelled back to the home country. This knowledge helps both the TNC and the innovation system in which it operates. However, such reverse transfers are likely to be significant only if the host country is technologically advanced (Kogut and Chang 1991). Depending on the extent of diffusion at home, reverse transfers can improve the productivity of the TNC, its vertically related enterprises (suppliers and buyers), its competitors and the knowledge institutions with which it interacts.

TNCs from the Republic of Korea and Taiwan Province of China have long located R&D centres in the United States, Europe and Asia to gain access to new technologies (chapter V). Such technologies have been applied in the home country to develop new products and processes for global markets. More recently, companies from China and India have set up R&D units in the United States and Europe (chapter IV).

There are relatively few empirical studies of the extent to which productivity growth in home countries can be attributed to spillovers from overseas R&D, and most relate to developed countries. The evidence suggests that the extent of reverse technology transfers hinges on the purpose of the R&D. Studies of Japanese TNCs suggest that the scope for positive effects on the productivity of firms in the home country is large when foreign affiliates undertake "innovative" R&D that tap into advanced knowledge centres abroad (Todo and Shimizutani 2005). Adaptive R&D by foreign affiliates of Japanese TNCs, drawing on technology developed in Japan, served to improve productivity in the host country but did not contribute to enhanced productivity in the home country.[30]

TNCs from the United Kingdom that have R&D investment in the United States have benefited from reverse technology, and the effects were particularly important in the case of R&D units set up to source technology (Griffith et al. 2004). Meanwhile, foreign R&D by Swedish TNCs does not appear to have generated significant spillovers in the home country, either at the firm level or the industry level (Braconier et al. 2000, Fors 1997), possibly because much of this R&D is of the adaptive type drawing on technologies developed at home (Håkanson and Zander 1986, Håkanson 1992).

A cross-country study of 152,000 firms in 30 countries concluded that outward-FDI-induced R&D had a positive impact on the home country's level of domestic innovation as measured by patenting activity (AlAzzawi 2004). Such benefits were found in both developed countries and in the newly industrializing economies. However, productivity benefits were found for newly industrializing economies but not for developed countries, suggesting that overseas R&D may be particularly beneficial for less advanced home countries.

3. Market expansion implications

Whereas adaptive R&D does not seem to generate significant reverse knowledge transfers to the home economy, it may generate other positive effects such as promoting market expansion. Such R&D is typically performed to expand sales in a foreign market by adapting a TNC's products or processes to suit local preferences and requirements. With the expansion of markets abroad, demand for material, inputs and services procured in a home country for global operations is likely to increase.

In some cases products developed by local R&D cater exclusively to the local needs (Behrman and Fischer 1980, Bartlet and Ghoshal 1991), while in others an expanded product line as a result of local R&D may subsequently benefit sales in global markets as well (box VI.7). If local adaptive R&D evolves into innovative R&D because a host market becomes a test bed for product applications in the regional or global market, or because it reaches a certain size, the original adaptive R&D can open up opportunities for expansion in other countries as well (box VI.8).

4. Home country concerns

The expansion of R&D by TNCs in their foreign affiliates in the Triad, and, more recently, also in parts of the developing world, has given rise to some concerns even among the most advanced home countries. The fact that TNCs now consider a new set of locations as candidates for R&D activities has led some observers to call for government intervention to mitigate possible risks associated with this development. Concerns are related to the possible consequences of R&D abroad replacing domestic R&D, relating to a hollowing out of the home economy NIS and a loss of skills. A recent report from the American Electronics Association is illustrative:

> "As the United States takes its leadership for granted, countries around the world have caught on and are catching up. While we begin to close our doors to the best and the brightest minds, these talented individuals and the intellectual property and jobs they create here are lured elsewhere. As we cut funding for research and development (R&D) – a critical factor in the innovation that has driven our economy for a century – other countries are investing in R&D, scientific education, and high-technology infrastructure... Americans may be surprised if the next revolutionary technology is produced abroad, but we should not be" (American Electronics Association 2005, p. 5).

There may be cause for concern if TNCs reduce R&D at home due to perceived weaknesses in the home-country NIS. Given the rapid pace of technical change, such adjustments are often slower than the technological needs of firms, potentially resulting in "systemic inertia" (Narula and Zanfei 2004). Firms may then acquire the technology they need from foreign countries or invest in R&D abroad to draw on other countries' NISs (Narula 2002). The problem, however, lies not in TNCs seeking to retain their competitive position, but in the structural weaknesses of the domestic innovation system. The correct policy response would be to address structural weaknesses, not to prevent local firms from competing effectively.

It is easy to overstate the risks of R&D internationalization. Innovating firms rarely shut down their domestic R&D completely: this would

Box VI.7. Nestlé's R&D centre in Singapore

Nestlé (Switzerland) established an R&D centre in Singapore in 1979 as part of its global R&D network. Its main function was to develop Asian-style convenience foods that were specifically suited to the various cuisines, preparation techniques and eating habits within the Asia-Pacific region. The development of culturally sensitive products such as food and beverages requires local presence.

This R&D unit's main activities focused on creating new rice, cereal and noodle products for markets in Asia and the world; developing new flavours through fermentation and enzyme reactions; and bringing out new seasoning and cooking aids for the Asia-Pacific markets through traditional food ingredients, spices and herbs. It was able to draw upon scientific knowledge held within Nestlé's global R&D network as well as on the specific knowledge related to product development.

The R&D also contributed to the expansion of the knowledge base of Nestlé's global R&D network, relating to Asian cuisine and customer habits. For instance, when Nestlé's R&D unit in Sweden developed the frozen vegetable product "Taste of Asia", staff from Sweden went to Singapore to learn the cuisine. This product is now marketed all over Europe. Similarly, staff from the Singapore unit assisted in introducing Asian noodle production in Europe.

Source: Reddy 2000, pp. 138-143.

risk losing valuable technological links at home, presumably the original base for the firms' competitive advantages.

Weaknesses of the home country innovation system may arise from the shortage of good researchers, the rising cost of conducting R&D or the lack of a manufacturing base with which researchers can interact. In science-based industries in particular, R&D may require a critical mass of researchers in different disciplines (De Meyer and Mizushima 1989). If this critical mass is not available at home, TNCs have to locate R&D in countries that can offer a suitable pool of talent. Even if it is available, bottom-line considerations may lead them to do R&D abroad to lower costs or to interact with manufacturing facilities. As manufacturing is offshored, segments of innovative R&D have to move with it. These factors have been important in attracting chip design to East and South-East Asia, for example (chapter V).

A growing global supply of skilled people at lower costs is a strong incentive for TNCs to expand R&D abroad rather than at home. For some work categories this can lead to loss of research jobs at home as well as downward pressure on researchers' wages. At the same time, given the growing need for R&D to respond to increased competition in international markets and to keep up with new technologies, the

Box VI.8. Mobile telecommunications R&D by TNCs in China

Since the early 1990s, China's mobile telecommunications market has expanded rapidly to become the world's largest in terms of both network capacity and number of subscribers. Rapid infrastructure build-up has encouraged many telecom equipment makers to invest in local production in the country. These enterprises also engage in local R&D in China (box table VI.8.1), which has come to play an increasingly important role in new product development.

Box table VI.8.1. R&D by selected TNCs in mobile telecoms technology in China, 2004

Company	Number of R&D centres in China	Number of R&D employees in China
Motorola	15	1 300
Nokia	5	800
Ericsson	9	700
Siemens	4	..

Source: UNCTAD, based on Chinese newspaper accounts and information from companies.

Initially the main function of these R&D centres was to adapt technology developed by the parent company to the specific market requirements in China. However, since mobile telecommunications products are highly standardized and the size and sophistication of the Chinese market has been rapidly increasing, local adaptive R&D has evolved into global innovative R&D. For example, in the case of mobile handsets, the Nokia 3610 model, introduced to the Asia-Pacific market in 2002, was the first product developed entirely by the Nokia Product Development Centre in Beijing. Now every tenth mobile handset sold globally by Nokia has been designed in Beijing.[a] Examples of globally oriented R&D centres in China include Nokia China R&D Centre (1998), the Motorola China Research Institute (1999), Nortel China R&D Centre (2001), Ericsson China Central R&D Institute (2002) and Sony Ericsson's global R&D centre in Beijing (2004).

Many of the R&D centres have capabilities in the area of 3G technologies and now develop products for both the Chinese and global markets. Nine cities in China host 3G-related R&D centres owned by foreign TNCs or domestic companies (Huawei and ZTE), with emphasis on different global standards recognized by the International Telecommunication Union.[b] Although the Chinese Government has not granted 3G licences to telecom operators, 3G equipment developed and manufactured locally by both foreign TNCs and domestic firms has begun to supply the global market. In this way the R&D activities in China have helped the firms concerned expand their business in other locations as well, which in turn has had positive effects on their respective home countries.

Source: UNCTAD.

[a] "Ten percent of Nokia handsets are designed by its Beijing centre, which is developing products for market five years later", *West China Metropolitan News*, 17 September 2004.

[b] "3G R&D distributed in nine cities", *Southern Metropolitan News*, 16 November 2004.

increased internationalization of R&D may be paralleled by an increased demand for R&D skills in the home countries as well.

Even if it is the less sophisticated or non-core R&D activities that are offshored to developing countries, some researchers at home would have to be redeployed and some, at lower levels, might become redundant.[31] A long-term worry is that this might lead to "the disruption of the apprenticeship path".[32] New entrants to R&D will need more advanced skills to keep ahead of competition from other countries. This process would entail adjustment costs and institutional changes to match education and training to needs for new skills.

The risk of technology leakage is another concern. If R&D abroad results in the successful imitation of TNCs' technologies as well as of other technologies developed in the home country by foreign competitors, home countries may be worried that it may reduce the demand for their products in the short term. In the longer term, a home country may fear losing control over some key technologies, with an erosion of its strategic position in the global markets (OECD and Belgian Science Policy 2005).

It is important, however, to keep current developments in perspective. The volume of R&D that developing countries now attract is small from a global perception. While there are segments in which developing countries offer attractive conditions for R&D, this does not mean that they have developed technological capabilities to match those in developed countries (Reddy 2000). Although a larger share of high value-added, knowledge-intensive activities is becoming subject to globalization, there is a long way to go before it can be considered a serious competitive threat. It does however sharpen the need for countries at all levels of development to ensure that their innovation systems have the skills needed to stay abreast of the technology race.

D. Conclusions

The internationalization of R&D by TNCs opens up new opportunities for developing countries with strong skills and a technological base to enhance the development of their innovative capabilities. It has important implications for developed countries as well as for the world economy as a whole. It is still too early to assess the full impact of these developments, but some implications are clear.

FDI in R&D can bring several benefits to host countries. While the empirical evidence is limited, what exists suggests that such benefits – strengthening the NIS, promoting human resource development, creating knowledge spillovers, upgrading industrial competitiveness – can be very important for developing countries.

Host countries attract innovative R&D by TNCs particularly in areas in which they have established a competitive advantage. In Italy, TNCs are more likely to undertake innovative R&D in medium-tech or low-tech industries. In India, strong domestic capabilities in the pharmaceuticals industry are now attracting TNC R&D in drug development. In China, similarly, the telecom equipment industry hosts some of the most innovative domestic firms as well as significant R&D by TNCs.

At the same time, these benefits do not appear automatically. The most important factor for realizing them is the *absorptive capacity* of the host country. Technological capabilities in the domestic enterprise sector and technology institutions are necessary not only to attract R&D but also to benefit from its spillovers. There may be tensions between TNCs and host governments in that the former may seek to retain their proprietary knowledge while the latter seek to promote as many spillovers as possible.

Although the benefits to developing countries from R&D internationalization are likely to outweigh the costs, the process can give rise to unwanted effects. Concerns may relate, for example, to the risk of foreign affiliates attracting the best scientists and engineers from basic research, or to unfair compensation of local counterparts who collaborate with TNCs in R&D. These and other risks should be borne in mind by governments when designing and implementing policies.

The nature of benefits to a host country depends on the type of R&D conducted, and on whether the R&D is linked to production. Generalizations are difficult, but a host country is likely to benefit more when the results of R&D are used in the host country and when the R&D involves intense interaction between the TNC and local firms and institutions. R&D-related technology sourcing may give rise to some concern among developed host countries of technology leakage. In developing host countries the main potential costs are related to the risk of crowding out in the labour market, the closure of R&D units after acquisition, and insufficient compensation for contributions to innovation when collaborating with TNCs.

The implications for home countries also depend on the type of R&D. It appears that technology sourcing and innovative R&D can generate significant knowledge spillovers to the home economy, especially in developing countries. The establishment of an R&D presence in leading technological centres abroad offers a potentially important way to link up with TNC R&D systems. Adaptive R&D abroad aimed at supporting sales in foreign markets is also likely to benefit home countries by improving the competitiveness of their TNCs and increasing indirect exports.

At the same time the expansion of R&D to developing countries, motivated by weaknesses in the NIS of home countries or by lower R&D costs has given rise to concern in home countries, especially with regard to the risk of hollowing out and loss of jobs. Such offshoring is so new that its assessment has to be tentative. Protectionist measures to limit the offshoring of R&D by TNCs are unlikely to be effective in addressing the root causes. In fact, restricting the ability of firms to raise their R&D efficiency will have negative impacts on their competitiveness.

Instead, it will become more important to explore new ways of collaborating with the new R&D locations, such as through joint research programmes and outsourcing as well as through inward and outward R&D-related FDI. As developing countries increase their number of university graduates, the historical near-monopoly of developed countries on scientists and engineers and other highly educated workers is diminishing. Moreover, to the extent that a larger proportion of researchers and scientists from developing countries decide to stay in their own countries instead of migrating to Europe or the United States, the latter economies may have to rely more on developing their own domestic base of human resources.

This makes it increasingly important for developed countries to consider ways of making their NISs more competitive, for example, by removing bottlenecks and addressing "systemic inertia", and by identifying niches where they are particularly strong. Similar to the case of offshoring of services in the broadest sense (*WIR04*), R&D internationalization may require appropriate policy responses to assist those workers who are directly affected. Adjustment to any change in employment patterns calls for greater labour mobility and changes in the skills profile. In general, countries now face greater pressure to make the necessary adjustments in their institutional framework to enable their workers as well as their firms to move up the technology and skills ladder – also in the area of R&D.

For the world economy as a whole, the internationalization of R&D should help speed up the innovation process. By bringing more national systems of innovation closer together it should also facilitate more cross-border flows of knowledge and technology.

In the short to medium term, however, most developing countries are not in a position to benefit from R&D internationalization. Many lack the skills and institutions to attract foreign R&D. Given the growing importance of technological and innovative capabilities for competitiveness, this may be a cause for concern. Countries that do not connect with these networks risk falling further behind in terms of technological and innovative capabilities. There is no “quick fix” to this problem, but there are vital long-term policy issues that need to be addressed now. The next chapter deals with some of these.

Notes

1 For example, information may be exchanged between foreign affiliates and TNC headquarters in the form of tacit knowledge or understandings that are not described in a patent. Patent data may underestimate the true degree of technology and knowledge transfer that has been possible. Similarly, patenting is a relatively new activity in many developing countries. Some countries may have been innovative but may not have seen the importance of patenting their ideas.

2 For a discussion on the potential impacts of different types of R&D by foreign affiliates on a host-country NIS, see Pearce 2004.

3 See “A new transnational capitalist class? Capital flows, business networks and entrepreneurs in the Indian software industry”, *Economic and Political Weekly*, 27 November 2004.

4 TNCs tend to internalize their most valuable technologies rather than sell them to unrelated parties (*WIR99*).

5 Source: various news articles.

6 This centre has filed 240 patents in the United States and has already been granted 25 (see “Eastern rebirth

of the life sciences", *Financial Times*, 10 June 2005).

7 Tacit knowledge may include cognitive capacity, experience and skills, or knowledge of routine, organizational structure, practices and norms.

8 See, for example, "Research labs power China's next boom", *International Herald Tribune*, 13 September 2004.

9 See "From the third type of fortune to the birth of tycoons", *New Fortune*, 28 April 2005 (in Chinese), "Dexin lands successfully in NASDAQ, raising $142 million", www.tom.com, 7 May 2005 (in Chinese).

10 When a firm that is applying for a patent cites patents previously taken out by other firms, it indicates that there has been a path of learning and knowledge, from the first firm to those that followed its R&D trail.

11 Foreign affiliates made up the majority of the 445 firms in the sample.

12 Foreign affiliates account for 47% of business R&D in the Czech Republic (chapter IV).

13 This result was sustained even after controlling for other explanatory factors relating to firms' industry sector and location.

14 This accords with the upgrading process of enterprises in some East Asian economies that have made the transition from original equipment assembly (OEA) to original equipment manufacture (OEM), to own design manufacture (ODM) and own brand manufacture (OBM).

15 The impact of the innovative R&D on domestic innovative capability and possible spillover effects may, however, be at least as important as for adaptive R&D.

16 Developing countries may even experience "immiserizing growth" if they become locked into stagnant incomes as producers face intense competition and are engaged in a "race to the bottom" (Hubert 1995, Kaplinsky and Readman 2000, UNCTAD 2002a).

17 By early 2003 the Pudong New District had attracted 66 FDI projects in microelectronics with investments totalling $8 billion. See "Shanghai Pudong New District tries to establish a world-class industrial base in microelectronics", *China News Agency*, 15 March 2003.

18 Shanghai Economic Commission "Shanghai's IC industry is leading the country", 2 February 2005.

19 "Happiness and worries coexist in Pudong's microelectronics industry", *Shanghai Securities News Capital Weekly,* 12 December 2003 (www.stocknews.com.cn).

20 About 70% of all acquisitions are based on a market-driven rationale (Kutschker 1989, p. 12, Granstrand et al. 1993, p. 416, Håkanson and Nobel 1993b, p. 402).

21 "Technology transfer from TNCs to China: new trends and policy measures", article posted on the website of MOFCOM 17 January 2005 (www.chinafdi.org.cn).

22 The companies were located in Croatia, the Czech Republic, Hungary, Latvia, Poland and Slovenia.

23 In part this is attributed to the Canadian Government's support of its research activities from 1962 to 1983 (Rugman and D'Cruz 2003, p. 146.)

24 The experience of joint research with TNCs in the aerospace industry in the Russian Federation, for example, suggests that local experience with the patenting and marketing of innovative outputs, as well as the legal and regulatory environment, are both critical in this regard (Ivanova 2004).

25 While an element of crowding out may also apply to infrastructure, such physical capital can be expanded more easily than human resources (Pearce 2004).

26 "Yet another sector embraces outsourcing to Asia: life sciences", *International Herald Tribune*, 25 February 2005.

27 However, TNCs might be restrained from doing this because if the drugs being tested are for consumption in developed countries, clinical trials need to be carried out on patients that have similar health and nutritional standards as those of the developed countries.

28 "Innovative Asia: how spending on research and development is opening the way to a new sphere of influence", *Financial Times*, 9 June 2005.

29 PalmOne's designers provided the product specifications, chose the key components and set the performance needs of the product. HTC carried out much of the mechanical and electrical design (Engardio et al. 2005).

30 A study of Japanese TNCs' R&D activities in the United States reached similar findings. A positive impact on the parent company's R&D productivity in terms of patents was noted for "research activities" by the foreign affiliates, but no such effect was observed in the case of "development-oriented R&D" (Iwasa and Odagiri 2004).

31 Such concerns have been voiced, for example, in the area of software development (e.g. British Computer Society 2004).

32 "Innovative India", *The Economist*, 3 April 2004.