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INTRODUCTION

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CHAPTER III

INNOVATION, R&D AND DEVELOPMENT

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INTRODUCTION

Bridging the technology gap between countries is necessary to foster sustainable economic development. Technology is advancing faster than ever before. Developing countries that fail to build capabilities enabling them to participate in the evolving global networks of knowledge creation risk falling further behind in terms of competitiveness as well as economic and social development. While international technology transfer can bring important knowledge to an economy, that alone is not enough. Using new technologies efficiently requires creating additional absorptive capacity, while a continuous effort has to be made to keep up with technical change. This is particularly true given the fact that wages tend to rise as a country develops, facilitating the entry of lower cost competitors in the market. While actions of both domestic enterprises and the government are essential to build technology capabilities in developing countries, TNCs can also play a role.

One of the main reasons why developing countries promote inward FDI is indeed to link up to the global technology and innovation networks led by these firms. In terms of creating new technology and diffusing it internationally, TNCs are world leaders in many industries. They account for the bulk of global business expenditures on R&D. They dominate new patents and often lead innovation in management and organization. Establishing links with their innovation and production networks can help countries enhance their technological capabilities and enable them to compete better in international markets.

Technological capabilities are difficult to acquire. The rapid pace of technical change and the growing importance of science-based technologies in many industries call for more advanced and diverse skills and intense technical effort. These require better infrastructure, not the least in information and communications technologies. They also require strong supporting institutions as well as stable and efficient legal and governance systems. Moreover, they require access to the international knowledge base, combined with a strategy to leverage this access for the benefit of local innovation systems. The cumulative forces that are increasing the gap between countries with respect to innovation performance make the role of policy increasingly important at all levels – national and international.

The manner in which TNCs allocate their R&D activities internationally is significant in this context. R&D is among the least internationalized functions of TNCs. Traditionally, when R&D internationalization took place, both home and host countries were found in the developed world. To the extent that TNCs undertook R&D in developing countries, they did so almost exclusively to adapt products and processes to local conditions. These stylized facts have begun to change.

These changes manifest themselves in several ways. First, the degree of R&D internationalization by firms is rising in all key home countries as part of the overall trend towards the offshoring of services (*WIR04*). German TNCs, for example, set up more foreign R&D units during the 1990s than they did during the preceding 50 years (Ambos 2005). Second, R&D internationalization is now growing fastest in some host developing countries, notably in Asia. Third, the drivers of R&D internationalization are changing. The process is no longer driven only by the need for local adaptation or to tap into established knowledge centres. In response to increasing competition, TNCs now relocate segments of R&D so as to access foreign pools of research talent, reduce R&D costs and speed up the process of technology development. Fourth, R&D in some developing countries now goes well beyond local adaptation and involves complex stages of R&D on a par with work undertaken in the developed economies. Fifth, developing-country firms are also setting up R&D units abroad. These trends have become apparent only in the past few years and are likely to continue.

This new phenomenon is partly expected and partly unexpected. It is expected in two ways. First, in most cases R&D undertaken abroad supports production. As TNCs increase production in developing countries, some R&D (of the adaptive kind) can be expected to follow. Second, R&D is a form of service activity. Many other services are fragmenting in a process whereby certain segments are located in countries with lower wages and appropriate skills. It is not surprising that R&D is following suit. Indeed, the survey of Europe's largest firms conducted in 2004 by UNCTAD and Roland Berger showed that all service functions – including R&D – are now candidates for offshoring (*WIR04*). It is unexpected in that R&D is a service activity with very demanding skill, knowledge and support needs — traditionally only met in developed countries with strong national innovation systems. Moreover, R&D is taken to be the least "fragmentable" of economic activities because it involves knowledge that is strategic to firms, and because it often requires dense knowledge exchange (much of it tacit) between users and producers within localized clusters. A home-country bias in R&D activities "reflects the linguistic and geographic constraints imposed by person-embodied exchanges and transfers of tacit knowledge" (Patel and Pavitt 2000, p 218).

The extent to which developing countries connect with the internationalizing R&D networks of TNCs depends in particular on the strength of their national innovation systems. This in turn is dependent on policies, the quality of institutions (including both organizations and the rules governing innovation activities), the quality of human resources and the production and innovative capabilities of enterprises. Innovation reflects an intense interaction between firms and other actors in the public and private sectors. Innovation in developing countries is often carried out on the shop floor, in process or product engineering, quality control, procurement, distribution and overall management. However, a significant part also involves technical effort in R&D laboratories separated from production. R&D-based innovation is greater the more advanced, fast changing and large-scale the technology involved, but it is needed even if it does not aim to push forward frontiers of knowledge.

Part Two of *WIR05* reviews recent trends in the internationalization of R&D by TNCs. It begins in chapter III by looking at the links between R&D, innovation and development, and considers the levels of innovative capabilities among countries around the world. Large gaps in this area prevail between countries — gaps that limit the ability of many of them to take part in the global networks of knowledge creation and diffusion. Addressing these gaps is a major development challenge; it is also essential to ensure that the internationalization of R&D by TNCs benefits larger parts of the world.

Chapter IV identifies the main players (firms and countries) in the R&D internationalization process. The analysis is confined to R&D due to data constraints, but, where available, other qualitative information related to innovation, notably in services, is also considered. Chapter V discusses the changing drivers and determinants of R&D internationalization. Chapter VI reviews the implications of R&D internationalization for host and home economies, recognizing the difficulties involved in assessing the impact of this phenomenon. The last two chapters (VII and VIII) focus on policy implications at the national and international levels. They place particular emphasis on the need to promote interaction between TNCs and domestic players (firms and institutions) in national innovation systems.

CHAPTER III

INNOVATION, R&D AND DEVELOPMENT

A. Innovation matters for all countries

Innovative activity and capabilities are essential for economic growth and development. A recent report identifies science, technology and innovation as essential to achieving the Millennium Development Goals (UN Millennium Project 2005, Sachs and McArthur 2005). This is true for the industrialized countries that are at the technology frontiers, as well as for developing countries that need to catch up in terms of technology.

Given the large gap between the developed and developing countries in terms of technological advancement, the latter continue to rely heavily on technology transfer from the former in their development process. However, sustainable economic development requires that countries do more than simply "open up" and passively wait for new technologies to flow in. It demands active, continuous technological effort by enterprises, along with government policies that help firms attract technologies, use them effectively and innovate. Technology requires efforts to absorb and adapt; it has strong "tacit" elements that cannot be embodied in equipment or codified in instructions or blueprints. Tacit knowledge can only be transferred effectively if the recipient develops capabilities to learn and incorporate the knowledge. It must seek new information, experiment with the technology, find new ways of organizing production and train its employees in new skills. It involves not just the enterprise itself but also interaction with other firms and institutions.

The development of technological capabilities has always been necessary for the effective use of new technologies; all the more so today. Greater openness to trade and capital flows does not reduce the need for local technological effort – on the contrary. Technologies are changing more rapidly, falling transport costs and liberalization are intensifying competition, and TNCs are seeking locations with strong capabilities to produce efficiently. Moreover, it is not just export-oriented manufacturing that needs to be competitive; manufacturers selling to domestic markets have to compete against imports. Export-oriented services and primary activities need to use new technologies to remain competitive in world markets. The development of new capabilities applies to both technical functions and managerial ones: organizational and marketing innovation is as important as technical innovation to growth and competitiveness (Teece 2000).

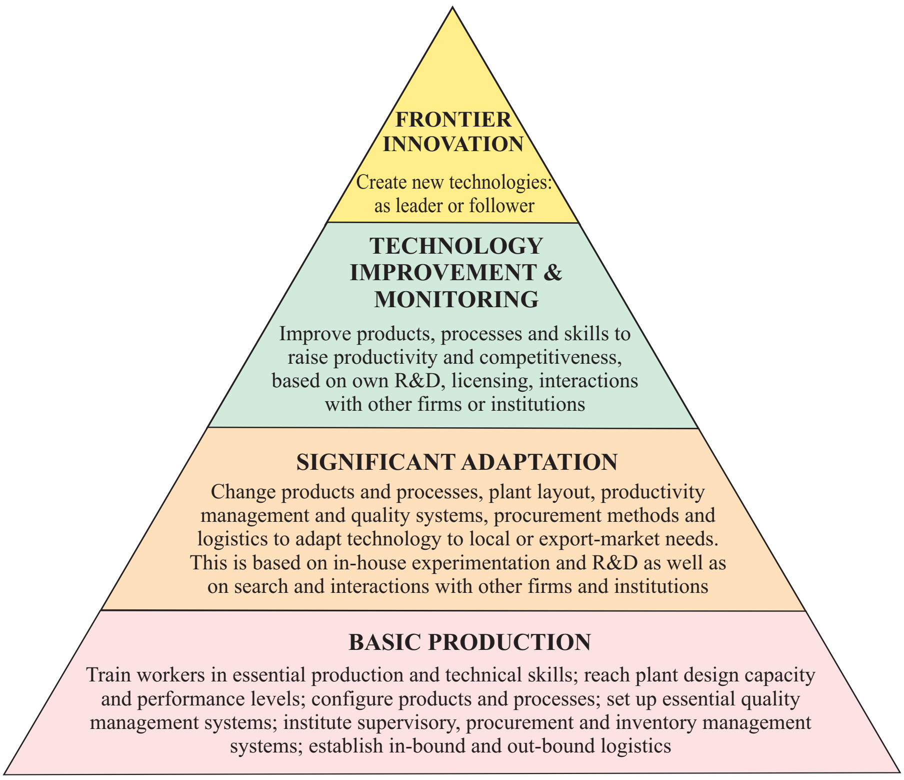
Technological innovation means the introduction of new products, processes or services into the market.[1] Innovation does not necessarily mean pushing the frontiers of knowledge, particularly in a developing-country context. Rather, innovations can be *new to the user* but not necessarily *new to the world*.[2] The nature of innovation – and of required capabilities – varies greatly between activities according to their technological complexity, the creation of new technology being at one extreme and the use of existing technologies at the other.[3] Figure III.1 shows an illustrative pyramid, with the least complex technological functions (in terms of innovative efforts) at the base, and the most demanding ones at the top.[4] While these categories are generic activities in all three sectors – primary, manufacturing and services – they can be adapted to different technologies to take account of particular machinery, process, product and organizational characteristics.

- The starting point is the acquisition of basic production capabilities to absorb and use existing technology. This sounds easy but it is not, at least in order for capabilities to match relevant global best practice and for activity that goes beyond simple assembly. Reaching internationally acceptable levels of production efficiency and quality in complex activities is very demanding. Many enterprises fail to do this, even after years of operation, unless they invest sufficiently in collecting information, creating new skills and developing appropriate management structures.

- Absorption and adaptation of technology are particularly challenging if conditions are significantly different from those at the origin of the technology, and if local support and supply structures are weak.
- Adaptation, in turn, can grow into significant technological improvement and technological learning, with systematic efforts made to improve product and process performance. At this stage, many firms start monitoring international technological trends and selecting those technologies that can feed into their own efforts.
- Finally there is the frontier innovation stage, when firms design, develop and test entirely new products and processes.

Research and development (R&D) is one source of innovation (box III.1). In the early stages of technological activity, enterprises need not set up formal R&D departments. As they mature, however, it becomes increasingly desirable to monitor, import and implement technologies. R&D as a distinct activity may appear as early as the second level of complexity, where multifaceted technologies are involved or if local conditions demand significant adaptation. In a developing country, such R&D is feasible once the operation is fairly large scale and the necessary technical skills are available. The role of formal R&D then grows as the firm attempts significant technological improvements to introduce new products or processes. Firms that reach the highest level in the pyramid need not, however, be frontier innovators (technological "leaders") – their R&D may build on or improve upon innovations done elsewhere (technological "followers"). A specialized unit not involved in routine technical or production work is needed to monitor new developments outside the firm or country, assess their significance for the firm and master, adapt and improve on existing technologies.[5] *Formal R&D becomes an essential part of the*

Figure III.1. Stages of technology development by innovation effort



Source: UNCTAD.

technological learning process, especially for complex and fast moving technologies.

Empirical studies suggest a direct relationship between R&D and growth.[6] The long-term impacts on economic growth of public R&D and business R&D have been found to be strong and significant (Guellec and van Pottelsberghe 2004a). Business R&D undertaken in other countries also plays an important role. Moreover, increased domestic business R&D accentuates the positive impact of both public and foreign business R&D. In other words, business R&D (either domestic or foreign-funded) has both a direct impact on a country's economic growth and an indirect one through improved absorption of the results of public R&D and R&D performed in other countries.

Enterprises are the principal agents of innovation today, but they do not innovate and learn in isolation. They rely on intricate (formal and informal) links with other firms and with public research institutions, universities and other knowledge creating bodies like standards and metrology institutes. In undertaking innovation, they react to government policies on trade, competition, investment and innovation. They seek human resources for innovation from the education and training system, and they draw upon the financial system for funding innovative efforts. The complex web within which innovation occurs is commonly referred to as the "national innovation system" or NIS (Nelson 1993, Lundvall 1992b).

Most of the NIS literature focuses on frontier invention in industrialized countries, rather than on mastery and adaptation of technology that take place in developing countries. However, the innovation system concept is just as relevant for the latter (UNIDO 2003, Edquist and McKelvey 2001). Most learning, mastery and adaptive activity requires close and continuous interaction with other enterprises like suppliers, subcontractors, competitors and consultants, as well as with other actors such as public R&D institutes, universities,

Box III.1. Definition of R&D

R&D is only one component of innovation activities, but it represents the most developed, widely available, and internationally comparable statistical indicator of industrial innovation activities.

According to international guidelines, R&D (also called research and experimental development) comprises creative work "undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications" (OECD 2002b, p. 30).

R&D involves novelty and the resolution of scientific and technological uncertainty. It includes basic and applied research along with development (United States, NSB 2004):

- *Basic research.* The objective of basic research is to gain a more comprehensive knowledge or understanding of the subject under study without specific applications in mind. In industry, basic research is defined as research that advances scientific knowledge but does not have specific immediate commercial objectives.
- *Applied research.* The objective of applied research is to gain the knowledge or understanding to meet a specific, recognized need. In industry, applied research includes investigations to discover new scientific knowledge that has specific commercial objectives with respect to products, processes, or services.
- *Development.* Development is the systematic use of the knowledge or understanding gained from research directed towards the production of useful materials, devices, systems or methods, including the design and development of prototypes and processes.

For data collection purposes, the boundary between R&D and other technological innovation activities can be found in pre-production development activities (OECD 2002b). In practice, however, it is difficult to make the distinction. In technology-intensive industries distinguishing between "research" and "development" is especially difficult since much of the R&D work conducted involves close interaction between researchers in both the private and public sectors, often also including close collaboration with customers and suppliers (BIAC 2005, Amsden and Tschang 2003).

Source: UNCTAD and Moris 2005b.

the metrology, standards, testing and quality (MSTQ) system, small and medium-sized enterprise (SME) extension services, venture capital funds and export marketing or training institutions. A good supportive institutional infrastructure is therefore important for effective innovation. Incentive structures that foster entrepreneurship, risk-taking and innovation at the firm, industry and university level are also important.

As the internationalization of production deepens and communication costs decline, each NIS increasingly draws on knowledge created in other systems. Rapid technical progress and the rising costs and risks of innovation force innovators to seek centres of scientific excellence internationally. Global production networks – in which TNCs play the leading role – link together the productive activities that underly innovation. Parent companies are instrumental in such networks, providing the initial technology to their affiliates and helping them absorb, adapt and subsequently upgrade it. As a result, the innovation systems of more and more countries are becoming interlinked in a global network in which technological activity is international and information networks span the world.

From an economic development perspective it is becoming increasingly important to take part in this international exchange. Those countries that are in a position to do so stand a better chance of accessing new technologies at an early stage, as well as commercializing innovations developed in their own NIS. However, the capabilities needed for participating are unequally distributed among countries (see below), which increases the risk of a further widening of already large development gaps.

While there are different ways for countries to participate in the international exchange of innovation (box III.2), *WIR05* focuses on the role of TNCs in this process, with special emphasis on the internationalization of R&D. As noted above, R&D is not always necessary for innovation. Due to data limitations, however, the analysis in Part Two is confined to this particular type of innovative activity. The next two sections describe the global allocation of R&D and of innovative capabilities. Subsequent chapters

Box III.2. Different ways of internationalizing innovation

There are three main categories of innovation internationalization (box table III.2.1). In the first category, national enterprises and TNCs as well as individuals are engaged in the international commercialization of technology developed at home. The second category relates to domestic and international technical and scientific collaborations among private and public institutions, including domestic firms and TNCs, universities and research centres. International innovation by TNCs is the third category. The TNC is the only institution that, by definition, can control and carry out within its boundaries the process of innovation across the globe.

Box table III.2.1. Taxonomy of internationalization of innovation

Category	Actors	Forms
International exploitation of nationally produced innovations	Profit-seeking (national and transnational) firms and individuals	• Exports of innovative products • Cession of licenses and patents • Foreign production of innovative goods internally designed and developed
International techno-scientific collaborations	Universities and public research centres National and transnational firms	• Joint scientific projects • Scientific exchanges, sabbaticals • International flows of students • Joint ventures for specific projects • Production agreements with exchange of technical information and/or equipment
International generation of innovations	TNCs	• R&D and other innovative activities both in home and host countries • Acquisitions of existing R&D units or greenfield R&D investment in host countries

Source: adapted from Archibugi and Michie 1995, Narula and Zanfei 2004.

Source: UNCTAD.

focus on the internationalization of R&D, the trend towards increased R&D by TNCs in developing countries, the driving forces behind this phenomenon, potential impacts and policy implications.

B. Global R&D trends

1. R&D is geographically concentrated

Between 1991 and 1996, global R&D spending increased from $438 billion to $576 billion (an average annual growth of 4.4%; annex table A.III.2). The momentum of R&D spending continued throughout the late 1990s and the beginning of the new millennium. By 2002 it had risen to $677 billion,[7] corresponding to an average annual growth rate of 2.8% since 1996.

R&D expenditure is geographically concentrated. In 1996 and 2002, the ten largest spenders accounted for more than 86% of the world total, with their share marginally increasing over that period (table III.1). Eight of them are developed countries, of which the United States reported by far the largest amounts in both years. Only two developing countries are among the top ten: China and the Republic of Korea.

Table III.1. The 10 leading economies in R&D and business R&D spending, 1996 and 2002
(Ranked by their 2002 values, billions of dollars)

Total R&D				Business R&D			
Rank	Economy	1996	2002	Rank	Economy	1996	2002
	World	575.6	676.5		World	376.3	449.8
1	United States	197.3	276.2	1	United States	142.4	194.4
2	Japan	138.6	133.0	2	Japan	92.5	92.3
3	Germany	52.3	50.2	3	Germany	34.6	34.8
4	France	35.3	32.5	4	France	21.8	20.6
5	United Kingdom	22.4	29.3	5	United Kingdom	14.5	19.6
6	China	4.9	15.6	6	Korea, Republic of	9.9	10.4
7	Korea, Republic of	13.5	13.8	7	China	..	9.5
8	Canada	10.1	13.8	8	Canada	5.9	7.9
9	Italy	12.6	13.7	9	Sweden	6.6 [a]	7.3 [b]
10	Sweden	8.8 [a]	9.4 [b]	10	Italy	6.7	6.6
	Total	495.8	587.6		Total	334.7 [c]	403.4
	Share in world (%)	86.1	86.9		Share in world (%)	88.9	89.7
	Developing economies, South-East Europe and CIS	44.5	57.1		Developing economies, South-East Europe and CIS	20.4	31.9
1	China	4.9	15.6	1	Korea, Republic of	9.9	10.4
2	Korea, Republic of	13.5	13.8	2	China	..	9.5
3	Taiwan Province of China	5.0	6.5	3	Taiwan Province of China	2.9	4.0
4	Brazil	6.0	4.6 [e]	4	Russian Federation	2.6	3.0
5	Russian Federation	3.8	4.3	5	Brazil	2.7	1.9 [e]
6	India	2.1	3.7 [b]	6	Singapore	0.8	1.2
7	Mexico	1.0	2.7	7	Mexico	0.2	0.8 [b]
8	Singapore	1.3	1.9	8	Turkey	0.2	0.4
9	Turkey	0.8	1.2	9	Hong Kong, China	0.2 [d]	0.3
10	Hong Kong, China	0.7 [d]	1.0	10	Chile	0.1	0.2
	Total	39.1	55.4		Total	19.7	31.5
	Share in developing economies, South-East Europe and CIS (%)	88.0	97.0		Share in developing economies, South-East Europe and CIS (%)	96.4	98.7

Source: UNCTAD, based on annex table A.III.2.

[a] 1995.
[b] 2001.
[c] In 1996, Switzerland was the 10th largest spender on business R&D ($5.7 billion). Thus, the total of the top ten in that year was $340.4 billion.
[d] 1998.
[e] 2003.

The growth in global R&D is partly due to increased expenditures by the largest spenders. Between 1996 and 2002, the growth in the R&D expenditure of the United States (5.8% per year) was twice as high as the world average. Canada and the United Kingdom also showed fast expansion during that period. The expenditures of China rose at an average annual rate of more than 20% during the same period. This dynamism contrasts sharply with the trends of France, Germany and Japan, where R&D expenditures actually contracted in dollar terms.[8]

The combined share of developing economies, South-East Europe and the CIS in global R&D spending is on the rise, although from a very low level. In 1991 they accounted for only 2.5% of the world total (annex table A.III.2). By 1996 their share had reached 7.7%, and by 2002 it had increased further to 8.4% (figure III.2). This increase was concentrated mainly in South, East and South-East Asia (table III.2), which accounted for a dominant and growing share in R&D expenditure outside developed countries (more than two-thirds in 2002). With the exception of West Asia, the share of all other subregions in the grouping dropped between 1996 and 2002. The decline was the most pronounced in Latin America and the Caribbean, the share of which shrunk from 21% to 16% of the total for the countries included in table III.2. Africa's share also declined from 2.2% to 1.9%.

The concentration of R&D expenditures outside developed countries is high and rising. The ten largest R&D spenders of the developing economies, South-East Europe and the CIS in 2002 accounted for 97% of all R&D in these economies (table III.1). Reflecting the dynamics of South, East and South-East Asia, six of the top ten are from these subregions. In the majority of these economies, R&D expenditure grew fast during the period. Double-digit annual growth rates were recorded for China, India and Mexico. R&D expenditures contracted in dollar terms only in Brazil.

In today's world economy, enterprises (private and State-owned) account for the lion's share of global R&D. In 1991, they spent $292 billion on R&D (annex table A.III.2). That amount increased to $376 billion in 1996 and $450 billion in 2002 (figure III.2). In other words, in each of these years enterprises were responsible for two-thirds of global R&D spending; the remaining one-third was accounted for by governments, higher education institutions and non-profit private entities.

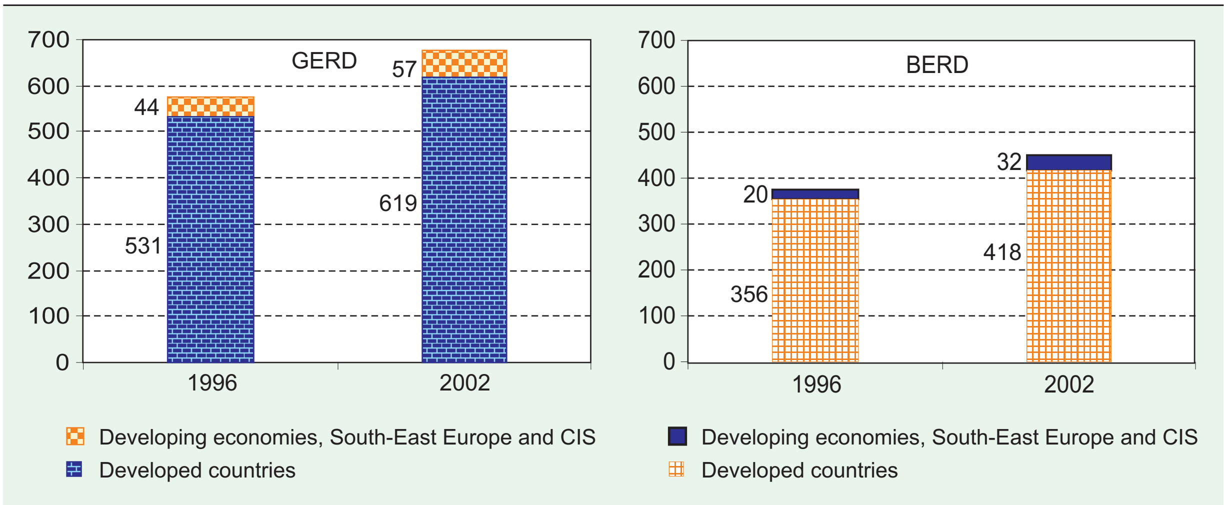
While the overall share was stable at the global level, the share of business enterprises in total R&D expenditure varied considerably by region and country (figure III.3). In the Triad – Japan, the United States and the EU – the share of enterprises was above 60% in 2002. Between 1996 and 2002 this share rose in Japan and the EU but not in the United States. In developing Asia, the share of enterprises rose rapidly over that period, reaching a level similar to that of the EU by 2002 (62%). Conversely, the share of enterprises in Latin America and the Caribbean was low and even declined in 1996-2002 (from 37% to 33%).[9]

Reflecting the dominant role of enterprise R&D in global R&D, the geographical patterns of the former show various similarities with those of the latter. R&D in the business sector is concentrated, just like total R&D. Both in 1996 and in 2002, the ten largest spenders on business R&D accounted for about 90% of the world total, their share marginally increasing over that period (table III.1). The list of the largest business R&D spenders is identical with that of the largest total R&D spenders; only the rankings vary. In a slight contrast to the global picture of total R&D, in business R&D only the spending of France, Italy and Japan declined in dollar terms in 1996-2002.

The share of developing economies, South-East Europe and the CIS in global business R&D spending is lower than in total R&D spending, reflecting a greater reliance on government R&D in these economies. Their share in the former reached only 5.4% in 1996 and 7.1% in 2002 (figure III.2). The top ten positions in terms of business R&D among the developing economies, South-East Europe and the CIS differ from those for total R&D only because data are not available from India, and the tenth place is thus taken by Chile (table III.1). Six of the ten economies are from South, East and South-East Asia. Another feature of the list of the largest business enterprise R&D spenders among the developing countries is its very high geographical concentration (the share of the largest ten is 99% of the group total in 2002), reflecting in part a lack of data reporting on business R&D in the majority of developing economies.

An output-based assessment of global innovation activities confirms the patterns observed above. Whereas developed countries

Figure III.2. Gross expenditure on R&D (GERD) and business enterprise R&D (BERD), by country group, 1996 and 2002
(Billions of dollar)



Source: UNCTAD, based on annex table A.III.2.

in 2003 still accounted for 83% of all foreign patent applications to the United States Patent and Trademark Office (USPTO), the share of developing countries and South-East Europe and the CIS has risen particularly fast. Between the periods 1991-1993 and 2001-2003, it jumped from 7% to 17% (annex table A.III.3). The annual average number of applications from these countries increased from around 5,000 to almost 26,000 between the two periods. South, East and South-East Asia showed by far the greatest dynamism, followed by South-East Europe and the CIS. Two economies (Taiwan Province of China, Republic of Korea) accounted for four-fifths of the total. They were followed distantly by India, China, Singapore, Hong Kong (China), the Russian Federation and Brazil. Asia accounts for more than 95% of the patents granted in the United States to recipients from developing, economies South-East Europe and the CIS. The share of patent applications from Latin America and Africa, on the other hand, fell from already low levels between the two periods (see also section IV.B.4).

Table III.2. Developing economies, South-East Europe and CIS: distribution of R&D, by region
(Per cent)

Region	1996	2002
South, East and South-East Asia	63.5	70.1
Latin America and the Caribbean	21.1	16.0
South-East Europe and CIS	11.2	9.6
West Asia	2.0	2.4
Africa	2.2	1.9
Total developing economies, South-East Europe and CIS	100.0	100.0

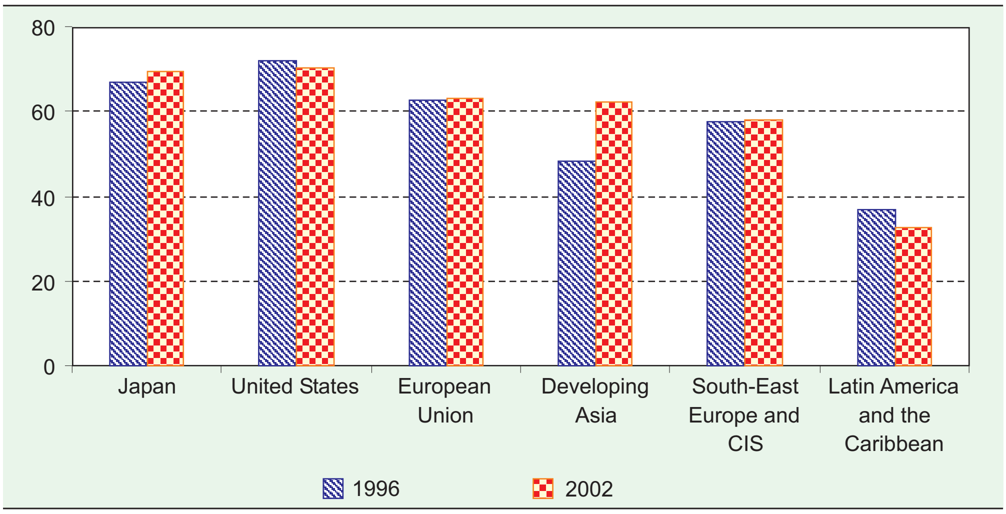
Source: UNCTAD, based on annex table A.III.2.

2. R&D by industry

Manufacturing firms have long conducted the bulk of business sector R&D in developed economies. In the United States, for instance, they accounted for 60% of company-funded R&D in 2001, with mining and extraction contributing only 0.5%, transportation 0.9% and utilities and construction 0.3% (United States, NSB 2004). However, the services sector also contributed significantly, with trade and other services together contributing 38% (see below). Within manufacturing, industries vary greatly in R&D intensity. For example, the OECD divides industries into four groups: *high technology*; *medium-high technology*; *medium-low technology* and *low technology* (table III.3).[10] The table is based only on the intensity of R&D; it does not necessarily depict the nature of the R&D conducted.[11]

R&D in services has traditionally been neglected in the literature, perhaps because of the assumption that services do not innovate or are primarily users of innovation in manufacturing (Howells, 2000; Tether 2004).

Figure III.3. Share of enterprise R&D in total R&D by country/region, 1996 and 2002
(Per cent)



Source: UNCTAD, based on annex table A.III.2.

Services do innovate in the broader sense in both processes (organizational change) and products (new services), but much of this innovation does not involve formal R&D. Data on this are therefore scarce, which makes empirical analysis difficult. This may be changing, however, as a result of new information and communication technologies (ICTs) and their growing role in service industries. The telecommunications and computer service industries have been investing in R&D for some time, and a new industry is now emerging that provides R&D services to manufacturers on a contractual basis (Tether 2002).

Data on services R&D are patchy. Published sources cover only a few industrialized countries up to 2000. However, they suggest that services R&D is rising in most economies, but that its share in total R&D varies greatly. Several countries showed substantial increases in services R&D from the early 1980s to the late 1990s; for instance, the shares of services in company-funded R&D increased by about 5 percentage points in France and Italy and 13 percentage points in Canada and the United Kingdom (United States, NSB 2004). The United States led the industrialized economies in terms of services R&D (box III.3). Interestingly, the R&D intensity of services (R&D as a percentage of sales) was higher than for manufacturing, though it also varied greatly by activity.

Table III.3. Classification of manufacturing industries by R&D intensity

Industry category	R&D intensity	Industries
High technology	>5%	Aircraft and spacecraft; pharmaceuticals; office, accounting and computing equipment; radio, television and communications equipment; medical, precision and optical instruments
Medium-high technology	1.5-5%	Electrical machinery and apparatus not elsewhere classified; motor vehicles, trailers and semi-trailers; chemicals excluding pharmaceuticals; railroad equipment and transport equipment not elsewhere classified; machinery and equipment not elsewhere classified
Medium-low technology	0.7-1.5%	Coke, refined petroleum products and nuclear fuel; rubber and plastic products; other non-metallic mineral products; building and repair of ships and boats; basic metals; fabricated metal products, except machinery and equipment
Low technology	<0.7%	Manufacturing, not elsewhere classified, and recycling; wood, pulp, paper, paper products, printing and publishing; food products, beverages and tobacco; textiles, textile products, leather and footwear

Source: United States, NSB 2004, Table 6-1.

Note: R&D intensity is direct R&D expenditures as a percentage of production (gross output).

3. Capability needs and benefits differ across activities

The efforts and capabilities required to master, adapt and create technologies, and thus to undertake R&D, differ. At the industry level, clothing manufacture is usually less complex in the range and depth of technical skills or information needed than making semiconductors. Within complex industries, technical processes may differ according to the speed of change and in the effort needed to create new generations of technology: steel technology today is more stable and less demanding in product innovation than electronics. Within any industry there can be differences according to product: in textiles, for instance, yarn spinning, a capital- and scale-intensive activity, requires more advanced technical skills than clothing manufacture. Finally, there are differences by function for any given product. In clothing, sewing is easier than designing new fashion products or managing an international supply chain.

There is a similar hierarchy of technical complexity in services, though it may be more difficult to define than in manufacturing. As noted in box III.2, some services now perform considerable R&D (indeed, the only output of contract research firms is research and development). Others do not conduct much formal R&D but innovate in terms of product development (e.g. new financial services by banks or new packages by tour operators) and management practices. In broad terms, service activities and functions can be ranked by the level of skills required – formal (education levels) or informal (employee training). In export-oriented services, for instance, the bottom end may include some call centres while the top end represents advanced R&D (*WIR04*).

Different types of R&D also yield *different benefits* in terms of adding value, learning, skill creation, productivity improvement, market growth and spillovers to other activities (chapter VI). Complex R&D activities generally call for, and so create, more advanced skills and knowledge than simple ones; they also yield higher value added. Activities associated with rapid technical progress offer better prospects for future productivity increase and enjoy faster growth than other activities.[12] Within a technology, advanced functions like design and development (as compared to basic production) provide higher value added and so higher wages. As innovation moves into higher functions, the NIS itself grows stronger and permits greater innovation in a more diverse range of activities.

The deepening of the industrial structure from simple to complex activities, and of innovative activities from simple to advanced functions, is a natural result of economic development, but accelerating and facilitating the process often requires active policies.[13] This applies not only to manufacturing but also to primary production (with the advent of biotechnology and genetic modification in agriculture), infrastructure and services (particularly those IT-based ones that are undergoing rapid offshoring, analysed in *WIR04*).

The R&D hierarchy for the manufacturing sector depicted above is actually a good representation of the industrialization process. Most developing economies start modern manufacturing with the simplest (low R&D) technologies: textiles, clothing, food-processing and wood products. Some move up the scale into heavy process industries (metals, petroleum refining) and metal products, providing basic intermediates. A few go on to become efficient users of "medium-high" technologies, making more advanced intermediate and capital goods (chemicals, automobiles, and industrial machinery). Even fewer develop competitive capabilities in high-technology industries like aerospace, micro-electronics or pharmaceuticals.

There is an important exception to this depiction, of special interest to this analysis. The "fragmentation" of production (i.e. the relocation of processes or functions across countries by TNCs to take advantage of differences in production and communication costs and skills) allows some countries without a strong R&D base to leapfrog to production in high-technology industries like electronics (Arndt and Kierzkowski 2001, Lall and Zhang 2004).[14] While developing countries generally start at the lowest level of technical complexity – final assembly – it *is* possible for them to move up the innovation ladder in electronics, taking on more demanding functions, handling more advanced equipment and making the more complex products.[15] For such science-based industries as biotechnology and some ICT-related industries, there may be limited need to locate the R&D activity in close proximity to production. As noted by one observer (Reddy 2000, p. 174): "because of their science base even theoretically trained personnel, with little or no industrial experience, can be employed for R&D functions in new technologies."

Box III.3. Services sector R&D in the United States

Service enterprises in the United States sharply increased their R&D spending and their share of total industrial R&D after the mid-1980s. Before 1983, service industries accounted for less than 5% of total industrial R&D; by 2002, their share reached 43%. The total value of R&D by services was $82 billion compared to $109 billion for manufacturing in 2002.

The amount of R&D by firms in service activities varied greatly (box table III.3.1). The leading performers were trade, scientific R&D services, software and computer systems design. With a combined R&D of $63 billion, they accounted for 77% of R&D by service firms.

The R&D intensity of service firms (R&D as a percentage of sales) is higher than that for manufacturing firms, though it also varies greatly by activity (box table III.3.2).

However, the classification of firms under service categories has to be treated with care. Companies are classified under various service activities on the basis of payroll, and the classification may be misleading as a result. This is particularly true of "trade". Thus, firms with a high payroll in sales and marketing are classified under "trade", and may include manufacturers with high marketing payrolls or diversified industrial conglomerates. One example of misclassification (noted by NSF) is that over $1 billion of biotech R&D in 2001 appears to have been performed by trading companies, when it is likely to have been performed by manufacturing companies.

Firms in software and computer systems design and related services jointly spent $21 billion on R&D in 2002, raising their share of total United States company-funded R&D from 4% in 1987 to 12% in 2002.

Scientific R&D services, the leaders in R&D intensity in 2001, are provided by companies that perform R&D for other firms on a contractual basis, mainly in manufacturing. R&D by these firms more than doubled during 1997-2001, showing both the rising pace of innovation and the growing willingness of manufacturers to outsource R&D previously kept in-house (Jankowski, 2001).

Health-care services are tightly linked to the high-technology pharmaceutical industry. Firms in these services have traditionally done relatively little R&D, but there was a sharp increase in 2002. The financial services and insurance industry, along with broadcasting and telecommunications, does very little. However, formal R&D may not be the best way to measure innovation in these industries, as they are constantly designing and introducing new products and processes.

Box table III.3.1. R&D spending by non-manufacturing activities in the United States, 2002
(Millions of dollars)

Total non-manufacturing	81 824
Mining, extraction and support activities	app. 700
Utilities	app. 100
Construction	164
Trade	app. 25 000
Information	17 870
Transportation and warehousing	app. 300
Newspapers, periodicals, books and databases	614
Software	12 927
Broadcasting and telecommunications	app. 1 600
Other information services	app. 2 600
Finance, insurance and real estate	1 903
Architecture, engineering, related services	4 159
Computer systems design, related services	11 983
Scientific R&D services	13 034
Other professional and scientific services	1 182
Management of companies and enterprises	148
Health-care services	app. 4 200
Other	app. 900

Source: United States, NSF (forthcoming), tables A-2, A-3. *Note*: Approximate (app.) figures are based on R&D funded by industry; data on federal funding of R&D are suppressed for confidentiality reasons, so that total R&D spending is also suppressed.

Box table III.3.2. R&D intensity: company and other (non-federal) R&D funds as % of net sales in R&D-performing firms

	2001	2002
All industries	3.8	3.6
Manufacturing	3.6	3.2
Non-manufacturing	4.0	4.1
Scientific R&D services	36.5	17.6
Software	19.3	21.4
Computer systems design, related services	16.5	14.3
Management of companies	7.8	7.6
Trade	6.2	5.0
Architectural, engineering, related services	5.2	5.3
Health-care services	4.1	15.1
Newspapers, periodicals, books, databases	2.7	2.8
Transportation and warehousing	2.4	0.5
Construction	1.4	0.6
Mining, extraction and support	1.3	3.2
Finance, insurance and real estate	0.7	0.6
Broadcasting and telecommunications	0.5	0.7
Information	4.4	4.0

Source: United States, NSF (forthcoming), table A-27.

Source: UNCTAD, based on information provided by NSF.

Some countries (Singapore among developing countries, Ireland among developed ones) have managed such upgrading rapidly; China appears set to follow suit. In other words, provided they have the absorptive capacity and appropriate policies and institutions in place, developing countries can take advantage of fragmentation to move up the technology ladder, both across activities and within them. The fragmentation of functions is proceeding even more rapidly in some services, as communication costs fall dramatically due to new information and communications technologies (*WIR04*). However, taking advantage of the potential of fragmentation requires countries to create knowledge and build local capabilities. As shown in the next section, the gap between the innovative capabilities of countries is very wide.

C. The innovation capability gap

1. Measuring innovation capabilities

In order for countries to connect with global networks of knowledge creation as well as to attract and benefit from R&D by TNCs, a certain basic level of innovative capabilities is needed. However, countries vary greatly in this respect, and in many cases the gaps between countries have been growing over time. In order to illustrate the current situation, *WIR05* introduces a new measure of national innovation capabilities: the UNCTAD Innovation Capability Index (UNICI). The UNICI measures two critical dimensions: (i) innovative activity (the *Technological Activity Index*) and (ii) the skills availability for such activity (the *Human Capital Index*). As it is not possible to measure national technological activity or skills directly, the indices use proxies. Since the data available even for the proxies are not complete (caveats are noted below) the indices should be interpreted with caution and seen mainly as broad indicators (box III.4).[16]

National innovative activity can be measured by its *inputs* or *outputs*. On the "input" side, the usual measures are R&D expenditures and/or employment. R&D is a narrow measure of innovation effort in that it does not capture informal technological effort; at the same time it is rather broad in that it includes defence and basic research that may not be relevant to the types of company R&D important for the present analysis.[17] Still, R&D data are the only ones available on a comparable basis across countries, and they provide an indicator of technical effort in complex activities (where the absorption of technologies requires formal R&D). As R&D expenditure data are more limited than R&D manpower data for a given year, only the latter appear in the index.

Innovation "outputs" are often proxied by patents (national or international) and scientific publications.[18] Data on patents taken out in the United States are singled out as they indicate that the innovation has reached a comparable level of novelty and is commercially valuable.[19] Patents are a better indicator of invention than of innovation, since they do not capture the commercial utility of the discovery; scientific publications are further removed from the market, though they do show the knowledge base on which technological activities depend.

The *human resource base for technological activity* is generally measured by educational enrolment. Enrolment data do not capture differences in the quality and relevance of the education; neither do they reflect skill development by learning on the job or other forms of employee training. Moreover, the available enrolment data are patchy and, in some countries, out of date. Again, they are the only data available for benchmarking skills and they do indicate differences in the education base on which technological capabilities are built.

These measures have to be normalized by economic size (say, population) to make them comparable across countries. However, where the absolute size of technological effort or skilled researchers matters (i.e. where there are minimum critical mass effects), it is also important to compare total values for economies. This is particularly relevant for the cross-border location of R&D (chapter V).

The components and variables of the UNICI are shown in table III.4. The three components of the Technological Activity Index are weighted equally while those making up the Human Capital Index are assigned different weights to capture the greater importance of high-level skills for innovation. The UNICI is calculated for 117 countries for the years 1995 and 2001. The starting year, 1995, was selected so as to include a large number of economies in South East Europe and the CIS.

The Technological Activity Index is shown in annex table A.III.4, with countries divided into four roughly equal groups. Its ranks were stable between 1995 and 2001 (with a correlation coefficient of 0.955). However, some countries changed ranks significantly. At the lower levels the changes generally arose from small shifts in one component, and so are difficult to interpret. At the higher levels they appear to be more clearly related to changes in technological effort. It should be noted that the Index does not capture the *absolute size* of the technological activities in each country, thus biasing the Index against countries like China or India with large rural populations, combined with large values for R&D spending. To the extent that the internationalization of R&D is affected by the absolute size of technological activity rather than its innovation intensity per capita, it is important to look at this factor as well (chapter V).

The Human Capital Index could be calculated for 119 countries.[20] The countries are grouped into three sets (annex table A.III.5). Most

Box III.4. Comparing the UNCTAD Innovation Capability Index with other indices

Various attempts have been made to benchmark national competitiveness and innovation, separately or together (all analysts accept innovation to be a vital ingredient of competitiveness).[a] A recent survey of many of the main indices found that they have several elements in common (Archibugi and Coco 2005).[b] All have variables for innovation inputs (R&D effort, measured by R&D spending or personnel), outputs (patents, nationally or in the United States) and human capital (different measures of education enrolment). Some also use scientific and technical journal articles, and some include variables for infrastructure (power and ICT). UNDP uses these infrastructure variables to capture technology diffusion (power for traditional technology and ICT for modern technology). The Rand index includes GDP per capita along with the number of universities and R&D institutions per capita. Some of these variables, like infrastructure, appear to be only remotely related to innovation; others, like GDP per capita, appear too broad to capture differences in technological capability.

The index which is probably closest to the UNICI is the Knowledge Index used by the World Bank (www.worldbank.org/kam). However, while the Knowledge Index encompasses 14 dimensions of knowledge capacities, the UNICI focuses on innovation capacity, drawing on a smaller set of variables. The UNICI weightings (especially with regard to human capital) are also different.

Broader competitiveness indices like the one calculated by the World Economic Forum (published in its annual *Global Competitiveness Report*) include subjective perceptions on the quality of innovation institutions, the strength of intellectual property protection, the aggressiveness of local enterprises in absorbing technology and the uniqueness of local product innovations.[c] These qualitative variables are not always reliable, however, as respondents from different countries may use different standards to answer the questions.

A merit of the UNICI is that it is based entirely on quantitative variables, and uses only those that are direct measures of technological activity and technical human capital. The technological activity component of the index uses R&D manpower,[d] patents taken out in the United States and scientific and technical publications (all deflated by population). The Human Capital Index uses literacy rates as the broadest indicator of skills, secondary enrolments as an indicator of workforce skills and tertiary enrolments as an indicator of high level skills. The components of the Technology Activity Index are not weighted, but those of the Human Capital Index are: higher levels of education are assigned higher weights because they are considered more important for technical and managerial innovation.[e]

Source: UNCTAD.

[a] See Archibugi and Coco 2004, IMD various years, Lall 2003, United States, NSB 2004, Porter and Stern 2001, UNIDO 2003, UNDP 2001, WEF various years.
[b] They discuss the UNDP index, their own ArCo index, the index developed by Lall and Albaladejo, 2002 and the Rand index (Wagner et al. 2001).
[c] For a detailed critique see Lall 2001b.
[d] The R&D manpower data were available for a larger number of countries than data for R&D spending.
[e] A simple weighting scheme of 1 for literacy, 2 for secondary enrolment and 3 for tertiary enrolment is used.

developed and some transition economies are in the leading group; this group also has four developing economies: the Republic of Korea, Taiwan Province of China, Argentina and Uruguay in that order. As with the Technological Activity Index, the Human Capital Index is stable over time, with a correlation coefficient of 0.973 between 1995 and 2001. Again, the absolute size of the skills availability is not captured by the index but is of importance for the international allocation of R&D internationalization (chapter V). The technology and skill indices are highly correlated (coefficients of 0.910 in 1995 and 0.889 in 2001), though technological effort and skill formation do not always go together.

2. The UNCTAD Innovation Capability Index

The *UNCTAD Innovation Capability Index (UNICI)* consists of the unweighted averages of the two indices mentioned above. Countries are divided into three groups: high, medium and low (table III.5). The high capability group in the UNICI comprises all developed countries (including the new EU members) as well as four developing and four South-East European and CIS countries (all from Europe). Three of the four developing economies are from South-East and East Asia; the fourth (Argentina) is from Latin America. The Asian ones combine strong technological and skill performance, while Argentina is weak in technology but somewhat stronger in skills. The economies in transition are in the top group mainly because of their skill base – their technological performance is relatively weak, with only one (the Russian Federation) in the high innovation group.

The "medium" capability group contains other South-East European and CIS economies as well as most resource-rich and newly industrializing economies (including China and two sub-Saharan African economies, South Africa and Mauritius). The "low" capability group has all the South Asian economies, one from South-East Asia (Indonesia), most sub-Saharan African economies and the remaining countries of Latin America, West Asia and North Africa. The rankings are in line with received knowledge about national capabilities. If some economies (like India) seem misplaced, the explanation lies in the use of total population as the deflator; while this is the correct way to construct the index, it can be misleading when minimum critical mass is important.

The unweighted regional averages for the UNICI are shown in table III.6. The developed countries are well in the lead, albeit with a slight decline in the average score. This does not mean that they are investing less in skills or innovation, but rather, that other countries are spending relatively more. The new EU members improved their scores during the period studied, approaching the levels of developed countries. The South-East and East Asia subregions are the clear leaders among developing regions, and their average score combined has improved over time. The West Asia and North African subregions also improved their performance, and overtook Latin America and the Caribbean, which had a deteriorating score between 1995 and 2001. South Asia also shows a lower score over time, mainly because of weaker technological performance by Pakistan and declining human capital performance by Sri Lanka. Sub-Saharan Africa improves its average score marginally but still lags behind all other regions.

Table III.4. Components of the UNCTAD Innovation Capability Index

Indices	Components	Weights attached
Technological Activity Index	R&D personnel per million population United States patents granted per million population Scientific publications per million population	All 3 components have equal weights
Human Capital Index	Literacy rate as % of population Secondary school enrolment as % age group Tertiary enrolment as % of age group	Weight of 1 Weight of 2 Weight of 3
UNCTAD Innovation Capability Index	Technological Activity Index Human Capital Index	Both indices have equal weights

Source: UNCTAD.

Table III.5. The UNCTAD Innovation Capability Index

High

	1995		2001	
1	Sweden	0.957	Sweden	0.979
2	Finland	0.947	Finland	0.977
3	Canada	0.947	United States	0.927
4	United States	0.946	Denmark	0.926
5	Australia	0.944	Norway	0.923
6	Denmark	0.934	Australia	0.920
7	Norway	0.929	Canada	0.907
8	United Kingdom	0.914	United Kingdom	0.906
9	Netherlands	0.912	Belgium	0.894
10	Belgium	0.911	Netherlands	0.888
11	Japan	0.906	Japan	0.885
12	France	0.902	New Zealand	0.879
13	Germany	0.889	Switzerland	0.877
14	New Zealand	0.874	Iceland	0.876
15	Switzerland	0.871	Taiwan POC	0.865
16	Austria	0.852	France	0.863
17	Taiwan POC	0.852	Austria	0.852
18	Iceland	0.835	Germany	0.850
19	Ireland	0.829	Korea, Rep. of	0.839
20	Korea, Rep. of	0.821	Spain	0.819
21	Spain	0.814	Ireland	0.814
22	Israel	0.808	Israel	0.804
23	Russian Fed.	0.797	Slovenia	0.801
24	Italy	0.781	Russian Fed.	0.788
25	Estonia	0.774	Estonia	0.775
26	Belarus	0.770	Singapore	0.748
27	Slovenia	0.763	Italy	0.746
28	Greece	0.733	Portugal	0.746
29	Ukraine	0.728	Lithuania	0.742
30	Singapore	0.719	Greece	0.737
31	Poland	0.717	Poland	0.732
32	Hungary	0.705	Hungary	0.725
33	Portugal	0.704	Ukraine	0.705
34	Georgia	0.683	Latvia	0.705
35	Bulgaria	0.671	Belarus	0.697
36	Lithuania	0.665	Czech Rep.	0.690
37	Czech Rep.	0.648	Argentina	0.685
38	Argentina	0.640	Bulgaria	0.665
39	Uruguay	0.617	Slovakia	0.626

Medium

	1995		2001	
40	Uzbekistan	0.605	Jordan	0.595
41	Hong Kong (China)	0.593	Georgia	0.593
42	Cyprus	0.581	Chile	0.576
43	Chile	0.581	Cyprus	0.566
44	Slovakia	0.580	Uzbekistan	0.564
45	South Africa	0.579	Hong Kong (China)	0.563
46	Armenia	0.574	Lebanon	0.555
47	Costa Rica	0.555	Romania	0.554
48	Latvia	0.554	South Africa	0.548
49	Romania	0.554	Brazil	0.529
50	Lebanon	0.538	Armenia	0.526
51	Kazakhstan	0.521	Kazakhstan	0.525
52	Kuwait	0.515	Uruguay	0.506
53	Venezuela	0.504	Kyrgyzstan	0.500
54	Moldova, Rep. of	0.497	Thailand	0.488
55	Saudi Arabia	0.496	Saudi Arabia	0.476
56	Bahrain	0.485	Egypt	0.474
57	Qatar	0.471	Kuwait	0.473
58	Tajikistan	0.454	Costa Rica	0.472
59	Mexico	0.454	Mexico	0.469
60	Philippines	0.452	Malaysia	0.467
61	Egypt	0.449	Bahrain	0.466
62	Peru	0.448	Venezuela	0.460
63	Turkey	0.430	Peru	0.425
64	Brazil	0.421	Philippines	0.423
65	Thailand	0.413	Moldova, Rep. of	0.413
66	Jamaica	0.394	Qatar	0.403
67	Malaysia	0.393	Jamaica	0.395
68	Mauritius	0.390	Colombia	0.393
69	Kyrgyzstan	0.370	Mongolia	0.391
70	Colombia	0.367	Turkey	0.390
71	Dominican Rep.	0.357	Bolivia	0.367
72	China	0.354	Tunisia	0.365
73	Zimbabwe	0.351	Tajikistan	0.362
74	Iran, Islamic Rep. of	0.349	China	0.358
75	United Arab Emirates	0.346	Iran, Islamic Rep. of	0.346
76	Jordan	0.339	United Arab Emirates	0.326
77	Sri Lanka	0.336	Mauritius	0.323
78	Morocco	0.324	Ecuador	0.319

Low

	1995		2001	
79	Mongolia	0.321	Sri Lanka	0.317
80	Tunisia	0.302	Botswana	0.315
81	India	0.287	Algeria	0.312
82	Bolivia	0.283	Viet Nam	0.295
83	Honduras	0.279	India	0.285
84	Ecuador	0.279	El Salvador	0.279
85	El Salvador	0.276	Zimbabwe	0.278
86	Indonesia	0.276	Morocco	0.277
87	Botswana	0.264	Indonesia	0.261
88	Namibia	0.261	Kenya	0.260
89	Algeria	0.257	Syrian Arab Rep.	0.246
90	Oman	0.234	Oman	0.232
91	Paraguay	0.233	Dominican Republic	0.221
92	Syrian Arab Rep.	0.225	Namibia	0.218
93	Viet Nam	0.218	Paraguay	0.213
94	Nicaragua	0.212	Nicaragua	0.179
95	Kenya	0.173	Honduras	0.174
96	Guatemala	0.165	Nigeria	0.157
97	Pakistan	0.160	Tanzania, United Rep. of	0.145
98	Zambia	0.150	Ghana	0.143
99	Nigeria	0.137	Uganda	0.140
100	Cameroon	0.133	Pakistan	0.137
101	Ghana	0.131	Guatemala	0.135
102	Côte d'Ivoire	0.129	Cameroon	0.134
103	Benin	0.118	Madagascar	0.133
104	Malawi	0.109	Yemen	0.130
105	Bangladesh	0.109	Côte d'Ivoire	0.127
106	Senegal	0.105	Bangladesh	0.121
107	Uganda	0.081	Zambia	0.115
108	Tanzania, United Rep. of	0.080	Benin	0.106
109	Yemen	0.079	Malawi	0.105
110	Mauritania	0.070	Senegal	0.101
111	Madagascar	0.065	Mauritania	0.068
112	Djibouti	0.057	Eritrea	0.054
113	Haiti	0.055	Ethiopia	0.051
114	Eritrea	0.047	Haiti	0.046
115	Ethiopia	0.046	Mozambique	0.030
116	Angola	0.022	Djibouti	0.028
117	Mozambique	0.018	Angola	0.019

Source: UNCTAD.

Note: The combined index is an unweighted average of the Technological Activity Index and the Human Capital Index.

Table III.6. Regional unweighted averages for the UNCTAD Innovation Capability Index

Region	1995	2001
Developed countries (excl. the new EU members)	0.876	0.869
The new EU members	0.665	0.707
South-East Europe and CIS	0.602	0.584
South-East and East Asia	0.492	0.518
West Asia and North Africa	0.348	0.361
Latin America and the Caribbean	0.375	0.360
South Asia	0.223	0.215
Sub-Saharan Africa	0.157	0.160

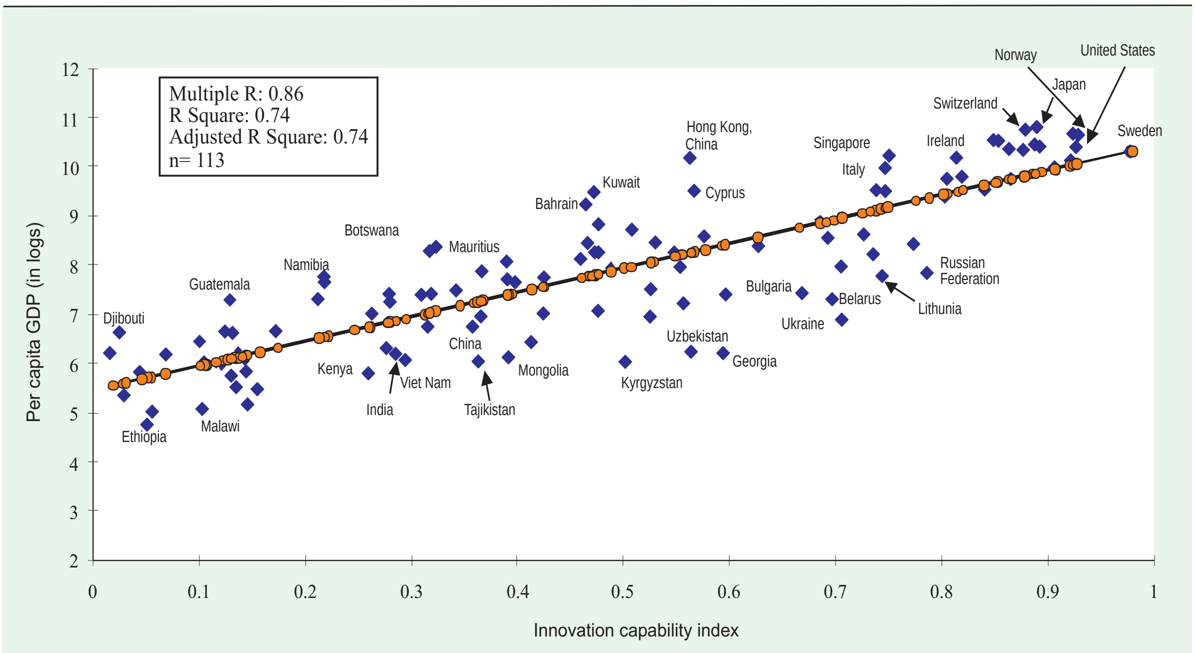
Source: UNCTAD.

Each of these three indices is highly correlated with income. In a regression analysis, the log of per capita income "explains" 75% of the variation in the Technology Activity Index in 2001, 66% of the variation in the Human Capital Index and 74% of the variation in the UNICI. As expected, technological activity, skills and incomes reinforce each other. The causal connections between the three are highly complex, and there are many possible feedback loops. For example, more technological activity leads to higher incomes, and higher incomes allow countries to invest more in innovation. However, it can be argued that the main causal link is likely to run from innovative activity and skills to incomes, and that innovative activity requires more advanced skills.[21]

Still, the indices do not rise uniformly with income levels. As the scatter diagram shows, there is a large variation around the regression line for the *UNCTAD Innovation Capability Index* (figure III.4).[22] Countries above the line have higher incomes than predicted by their innovation index value (i.e. scoring lower on the index than predicted by their incomes); those below the line score higher on the index than predicted by their incomes. Hong Kong (China) has the lowest composite innovation score in relation to its per capita income (presumably earning high income from service activities that do not require significant technological effort), followed by some small resource-rich economies. At the other end of the spectrum, various economies in transition have high composite scores relative to income, a result, as noted above, of their relatively strong performance in skill creation.

To sum up, there are large gaps between countries in terms of technological activity and human capital. The gap is not just between the developed and developing countries, but also within the developing and transition economies. In the developing world, innovative capabilities are highly skewed, with South-East and East Asia at the high end and sub-Saharan Africa at the low end of the spectrum. Within South-East and East

Figure III.4. Relationship between the UNCTAD Innovation Capability Index and log per capita GDP, 2001



Source: UNCTAD.

Asia, the three leaders (the Republic of Korea, Taiwan Province of China, Singapore) are well ahead of the other economies. Transition economies have large reservoirs of skills in relation to their income levels but seem to lag in technological effort.

While the Index suffers from the inevitable problems of finding the appropriate measures for technological effort and human capital, its use of hard statistics provides intuitively plausible results:

- Innovative capabilities differ greatly across countries, and the ranks are quite stable over the period considered. It is proving difficult for countries at the bottom to improve their position over time; there are cumulative forces at work that seem to reinforce the advantages of the leaders. It also suggests that significant change takes time to achieve.
- However, some countries have improved their ranking. Thus, while developed countries dominate the "high" group in the UNICI, that group also includes four developing economies and four economies in transition.
- The three leading developing economies have participated vigorously in the global production and innovation system, but each did so using different means to access technologies and build domestic capabilities.[23] Each invested heavily in education and skills development, since sustained progress in either strategy requires highly skilled human capital. Most fundamentally, in each case access to global technologies and to foreign markets was critical to sustained growth and upgrading.
- The main strength of the economies in transition, particularly those in Europe, lies in their human capital, rather than in technological activity, suggesting that there is scope for using the former to enhance the latter.
- South Asia and sub-Saharan Africa lag behind the other regions in innovation and, more particularly, in human capital creation.

What are the implications of these observations? The first, of course, is that innovative capabilities affect countries' ability to develop and raise living standards. In a globalizing world with rapid technical change, strong and growing innovative capabilities are essential to economic progress. This is as true of resource-based economies as of others, and it applies as much to services and agriculture as it does to manufacturing. As technological progress proceeds at an accelerating pace, and as the competitive pressure on firms intensifies, the demands made on countries' capabilities rise. This makes it more important than ever before to seek ways to bridge the gaps that exist.

Second, innovative capabilities are directly relevant to the location of internationally mobile R&D – the theme of *WIR05*. TNCs seeking R&D sites overseas look for adequate supplies of qualified technical manpower and innovative activity (chapter V). This is not to say that these are the only factors at work in their choices. Attracting global R&D, whether conducted in-house by TNCs or outsourced to local service providers, also needs such conditions as a stable and conducive investment climate, capable local firms, adequate ICT and other infrastructure, and intellectual property protection. But innovation capabilities – of the right quality and at the right cost – are clearly the *conditio sine qua non*.

Third, innovative capabilities also affect the scope for host-country benefits from internationalized R&D (chapter VI). The quality of R&D that is internationalized depends on local capabilities. The same applies to the resulting externalities, in terms of how much local firms and institutions are able to absorb and learn from exposure to best practice R&D techniques and skills. Whether or not R&D deepens over time, and how far it spreads over different activities, are almost entirely a function of the strength of the local skill and innovation system.

Finally, a word of caution. National innovative capabilities as measured above can be misleading where *minimum critical mass* considerations apply. While deflating technological effort and skill formation by the size of the economy is the right way to calculate a capability index, it skews the result against countries that have a large pool of employable skilled manpower with diverse skills, even with low rates of skill creation at the national level. Thus the absolute size of the stock of educated people has to be taken into account when considering the determinants of R&D location. This explains the relatively modest positions in the UICI rankings of China and India, two significant players in the recent increase in R&D internationalization by TNCs (chapter IV).

D. Conclusion

There is a co-evolution of economic development and technological complexity (by activity and function). The higher levels of skills and technological capabilities that accompany development permit countries to shift into more advanced activities and functions. More advanced activities and functions, in turn, yield higher value added, and allow countries to remain competitive despite higher wages. While this is a natural feature of the development process, countries can improve their innovative capabilities by appropriate policy interventions (chapter VII).

To summarize the main features of innovation highlighted above:

- Innovation is essential for economic development. Although in today's globalizing world economy developing countries can obtain new technology from other, more developed countries, they have to learn and innovate in order to use new technologies efficiently. As countries move up the development ladder and undertake more complex activities they need to upgrade their technological capabilities and undertake more advanced forms of innovation.
- The ways in which innovation takes place can be diverse, but an important source of innovation is through R&D. Formal R&D becomes essential at a certain stage, certainly in manufacturing, and increasingly in some kinds of modern services and agriculture.
- Enterprise innovation involves interactions with other firms and institutions: technology development is a systemic process. Given the externalities, coordination problems and public goods (basic research, testing, metrology) inherent in this process, government involvement is vital particularly in the early stages. In fact, without appropriate industrial, technology and education policies, R&D in the business sector is unlikely to take off (chapter VII).
- Business R&D is geographically and sectorally concentrated. While the bulk is undertaken in developed countries, R&D in some developing countries – especially in developing Asia – is expanding particularly fast. Most R&D takes place in manufacturing, but it is also growing in the services sector.
- Technological advances worldwide, especially in ICT, have created new opportunities for developing countries to participate in global knowledge networks once they have the necessary capabilities. At the same time, minimum entry levels are rising in terms of the capabilities required. The cumulative nature of capability building, together with scale and agglomeration economies, means that the successful early starters can continue pulling ahead of latecomers that are unable to reach the minimum entry levels. Policy intervention is necessary to reverse this trend.
- Innovation – and especially R&D – increasingly needs constant access to international knowledge. All "late industrializers" tapped technical knowledge and skills from the early starters, though in different ways. While there are various ways to link up with global knowledge networks, inward and outward FDI in R&D is perhaps the most direct way in which a country can connect with centres of knowledge in other countries.
- National innovation systems are becoming increasingly interdependent. The absence of local capabilities can effectively limit interaction between one system and the rest of the world, and thereby condemn the system in question to isolation from the mainsprings of technical change and competitiveness.

The extent to which developing countries can link up with global networks of learning and knowledge creation depends on their national innovative strengths. These strengths differ greatly, and the UNCTAD Innovation Capability Index shows that gaps between countries tend to persist over long periods. While the early stages of development necessarily have to involve nurturing indigenous innovative capabilities in the public as well as in the private sector, TNCs can play a role in strengthening an NIS (chapter VI). But foreign affiliates do not always undertake high-level technological activities in host countries. Many developing economies have long had FDI in resource extraction, manufacturing and services without foreign affiliates doing R&D. What is new is that the trend is for more TNCs to spread R&D to some developing countries, to a degree and in ways not seen before. The next two chapters map this process and discuss the factors that drive its internationalization and location.

Notes

1 According to the so-called Oslo Manual: "Technological product and process (TPP) innovation comprise implemented technologically new products and processes and significant technological improvements in products and processes. A TPP innovation has been implemented if it has been introduced on the market (product innovation) or used within a production process (process innovation). TPP innovations involve a series of scientific, technological, organisational, financial and commercial activities." (OECD 1997a, p. 31).

2 A large body of "evolutionary" literature on technology argues that there is no essential difference between absorbing, adapting and improving technologies and creating entirely new technologies (Nelson and Winter 1982, Metcalfe 1995). There is also a growing literature in this tradition which analyses technological activity in developing countries, see, e.g. Bell and Pavitt 1993, Dahlman et al. 1987, Katz 1987, Ernst et al. 1998, Lall1992 and 2001a, Nelson 1990, Radosevic 1999, UNIDO 2003.

3 Several authors have classified technical functions by innovativeness. See, for instance, Bell and Pavitt 1993, Hobday 2001, Figueiredo 2001, Ernst et al. 1998, Lall 1992.

4 A more detailed classification of functions by levels of technical complexity is provided in annex table A.III.1.

5 Even in developed countries, much R&D (Cohen and Levinthal 1989 estimate it at about half) is of this type; R&D has "two faces": learning and innovation.

6 For a survey, see Guellec and van Pottelsberghe 2004a.

7 Data for at least one year's total R&D spending over the period 1996-2002 are available for 93 economies, including all the major R&D performers (annex table A.III.2). Additionally, partial data are available from 57 economies on business enterprise spending on R&D.

8 In national currencies, however, R&D expenditures increased somewhat in these economies as well.

9 Data on business expenditures on R&D are not available for African countries.

10 For updated versions, see Hatzichronoglou 1997 and United States, NSB 2004.

11 For example, it is possible that low-technology industries engage in more complex or fundamental research than do high-technology sectors.

12 Data on 70 economies that account for 97% of global economic activity show that high-technology manufacturing output grew at 6.5% per annum over 1980-2001, while other manufacturing output grew at 2.4% (United States, NSF 2004).

13 Government efforts to tap such technological differences date back to the beginnings of industrial policy in the 15th century (Reinert 1995). Countries have long tried to move their productive structures from activities with decreasing returns to those with increasing returns – initially from primary production to manufacturing and later, within manufacturing, from low- to high-technology activities. In modern economic theory, conditions of diffuse externalities with coordination problems and other market failures lead to multiple equilibriums, and so require coherent government intervention to move from low to high growth equilibriums (Hoff and Stiglitz 2001).

14 Other high-technology activities (e.g. in aerospace, precision instruments and pharmaceuticals), may not be suited to fragmentation because of security concerns, specific skill needs, continuous processes of production or scale economies.

15 Foreign technology and R&D facilities can also be acquired through outward FDI.

16 The UNCTAD Innovation Capability Index draws on the World Bank (2004) for data on literacy rates, tertiary enrolment rates, technical publications, R&D and general data on population and GDP; UNIDO (2003) for enrolments in technical subjects; the UNESCO website (www.unesco.org) for researchers in R&D and enrolments at primary and tertiary levels; the USPTO website (www.uspto.gov) for patents in the United States; the Eurostat website (europa.eu.int/comm/eurostat) for R&D data; and the RICYT website (www.ricyt.org) for R&D in Latin America.

17 Even formal R&D data are deficient. Many developing countries do not collect or publish them, or they provide very outdated information. Some data may not conform to internationally accepted definitions of what comprises R&D. For the purposes of industrial innovation, the most important variable in R&D internationalization, the best measure would be R&D conducted by enterprises. However, data on this component of R&D are even scarcer in developing countries than on total R&D, and this measure was not used here for this reason.

18 Some studies also use total factor productivity (TFP) to measure the "output" of innovation. However, comparable TFP data are difficult to obtain and the results are subject to severe methodological and interpretational problems at the national level.

19 While there are potential biases associated with the use of USPTO data, it is the least biased indicator (Dernis et al. 2001). Data on Triadic patents – taken out at the European Patent Office, the Japanese Patent Office and the USPTO – can reduce the "home bias", and may capture the most commercially valuable patents (since taking them out involves substantial costs). However, the number of Triadic patents is relatively small (around 44,000 compared to some 180,000 for USPTO patents) (OECD 2004b). They may also be biased against developing-country firms that tend to focus on patenting in the United States, which is the largest export market for many of them.

20 This was two more than the Technological Activity Index, but the extra two were dropped for the combined Index.

21 There might be a reverse causality between per capita income and the UNICI. Richer countries are better able to support education and innovation. In addition, countries with oil resources consistently display a higher per capita income than the UNICI would predict. At the same time, in poorer countries, it is likely that a higher human capital index leads directly to higher income, which in turn leads to higher technological capabilities and a higher value in the UNICI.

22 Only countries deviating significantly from the line are mentioned in the chart.

23 Singapore relied heavily on FDI and insertion into the production (and later, R&D) networks of developed-country TNCs (chapter V); the other two have relied more on arm's length technology transfers by TNCs, using original equipment manufacture (OEM) contracts and licensing as well as developing local technological and R&D capabilities (Lall 2001a).