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2005 Transnational Corporations and the Internationalization of R&D

CHAPTER IV

R&D BY TNCS AND DEVELOPING COUNTRIES

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R&D BY TNCs AND DEVELOPING COUNTRIES

TNCs are playing a major role in global R&D, not only through activities in their home countries but also increasingly abroad. The internationalization of R&D is not a new phenomenon. What is new is its faster pace in recent years and its spread to developing countries (albeit to only a few, mainly in Asia). Moreover, R&D activities in developing countries are no longer aimed at adapting technologies to local conditions only; they increasingly involve "innovative" R&D, including developing technologies for regional and world markets. At the same time, TNCs from developing countries are themselves investing in R&D abroad, primarily in order to access advanced technologies and research capabilities in developed countries, as well as to adapt products to new markets and tap sources of specialized expertise in other developing countries. This chapter maps these trends.

A. TNCs are dominant R&D players

TNCs account for a major share of global R&D. Indeed, with $310 billion spent in 2002 (United Kingdom, DTI 2004), the 700 largest R&D spending firms of the world – of which at least 98% are TNCs[1] – accounted for close to half (46%) of the world's total R&D expenditure and more than two-thirds (69%) of the world's business R&D (annex table A.III.2).[2] Given that there are an estimated 70,000 TNCs in the world (annex table A.I.8), this is a conservative estimate. It confirms earlier findings that in the mid-1990s TNCs already accounted for a very large share of the R&D expenditure of the Triad (Gassmann and von Zedtwitz 1999).[3]

In fact, the R&D spending of some large corporations is higher than that of many countries. In four TNCs (Ford Motor, Pfizer, DaimlerChrysler and Siemens), R&D spending exceeded $6 billion in 2003 (table IV.1). In another two (Toyota Motor and General Motors), it surpassed $5 billion. By way of comparison, in developing economies, South-East Europe and the CIS as a group, total gross expenditure on R&D (GERD) came close to or exceeded $5 billion in 2002 (the latest available year) only in China, the Republic of Korea, Taiwan Province of China and Brazil, in that order (table III.1). Even in large economies, such as India, Mexico and the Russian Federation, it remained well below the $5 billion mark. The same is true for such small, developed and R&D-intensive countries as Austria, Denmark and Finland (figure IV.1).

Over 80% of the 700 largest R&D spending firms come from only five countries: the United States, Japan, Germany, the United Kingdom and France, in that order (table IV.2). Only 1% of the top 700 are based in developing countries or South-East Europe and the CIS (table IV.1), although several have moved up the ranks since the late 1990s (United Kingdom, DTI 2004). Almost all these firms come from Asia, notably from the Republic of Korea and Taiwan Province of China (table IV.2), while only one is from Africa and two are from Latin America.

The 700 largest R&D spenders are concentrated in relatively few industries. In 2003, more than half of them were in three industries (IT hardware, automotive and pharmaceuticals/ biotechnology) (table IV.3).

Within each industry, the two largest R&D performing firms were responsible for very high shares. The two most concentrated industries

Table IV.1. The top 20 firms, by R&D expenditure in the world and in developing economies, South-East Europe and CIS, 2003

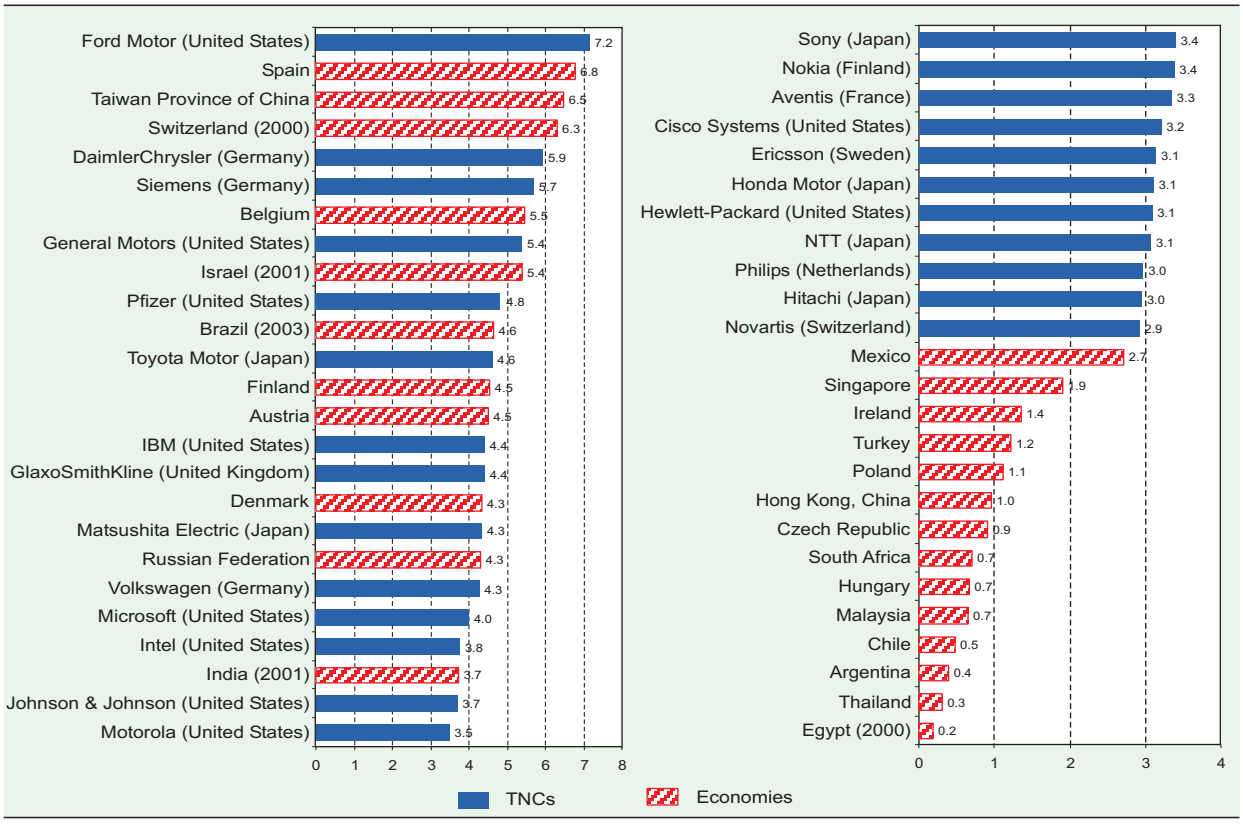
(Millions of dollars)

World				Developing economies, South-East Europe and CIS			
World rank	Corporation	Home economy	R&D spending	World rank	Corporation	Home economy	R&D spending
1	Ford Motor	United States	6 841	33	Samsung Electronic	Republic of Korea	2 740
2	Pfizer	United States	6 504	95	Hyundai Motor	Republic of Korea	734
3	DaimlerChrysler	Germany	6 409	110	LG Electronics	Republic of Korea	612
4	Siemens	Germany	6 340	178	Taiwan Semiconductor	Taiwan Province of China	342
5	Toyota Motor	Japan	5 688	219	PetroChina	China	265
6	General Motors	United States	5 199	255	Accenture	Bermuda	228
7	Matsushita Electric	Japan	4 929	258	Korea Electric Power	Republic of Korea	227
8	Volkswagen	Germany	4 763	267	KT	Republic of Korea	219
9	IBM	United States	4 614	298	Marvell Technology	Bermuda	197
10	Nokia	Finland	4 577	300	POSCO	Republic of Korea	196
11	GlaxoSmithKline	United Kingdom	4 557	317	Petroleo Brasileiro	Brazil	183
12	Johnson & Johnson	United States	4 272	328	SK Telecom	Republic of Korea	172
13	Microsoft	United States	4 249	337	China Petroleum & Chemical	China	167
14	Intel	United States	3 977	348	Winbond Electronic	Taiwan Province of China	158
15	Sony	Japan	3 771	349	Embraer	Brazil	158
16	Honda Motor	Japan	3 718	350	United Microelectronics	Taiwan Province of China	157
17	Ericsson	Sweden	3 715	486	Pliva	Croatia	99
18	Roche	Switzerland	3 515	516	Sasol	South Africa	91
19	Motorola	United States	3 439	518	AU Optronics	Taiwan Province of China	91
20	Novartis	Switzerland	3 426	585	Hyundai Heavy Industries	Republic of Korea	77

Source: UNCTAD, based on United Kingdom, DTI 2004.

Figure IV.1. R&D expenditure by selected TNCs and economies, 2002

(Billions of dollars)



Source: UNCTAD, based on annex table A.III.2 and United Kingdom, DTI 2004.

Table IV.2. Home economies of the 700 largest R&D spending firms of the world, 2003
(Number of companies and per cent)

Economy	Number of firms	Percentage of largest 700 R&D spenders
United States	296	42.3
Japan	154	22.0
Germany	53	7.6
United Kingdom	39	5.6
France	35	5.0
Switzerland	20	2.9
Sweden	15	2.1
Republic of Korea	10	1.4
Denmark	8	1.1
Taiwan Province of China	8	1.1
Netherlands	8	1.1
Canada	7	1.0
Belgium	6	0.9
Finland	6	0.9
Italy	6	0.9
Spain	4	0.6
Bermuda	3	0.4
Norway	3	0.4
Austria	2	0.3
Australia	2	0.3
Brazil	2	0.3
China	2	0.3
Ireland	2	0.3
Israel	2	0.3
Luxembourg	2	0.3
Croatia	1	0.1
Greece	1	0.1
Hong Kong, China	1	0.1
Liechtenstein	1	0.1
South Africa	1	0.1
Total	700	100.0

Source: UNCTAD, based on United Kingdom, DTI 2004.

Table IV.3. Industry breakdown of the 700 largest R&D performing firms, 2003
(Per cent)

Industry	Share of 700 companies' R&D expenditure	Share of two largest spenders within the industry
IT hardware	21.7	13
Automotive	18.0	21
Pharmaceuticals and biotechnology	17.5	18
Electronic and electrical	10.4	31
IT software and computer services	6.3	44
Chemicals	4.8	23
Aerospace and defence	3.9	35
Engineering	2.9	20
Telecommunications	2.2	58
Health-care products and services	2.2	33
Others	8.2	..

Source: UNCTAD, based on United Kingdom, DTI 2004.

were telecommunications (because of NTT) and software and computer services (because of Microsoft and IBM). The industry composition of the top R&D spenders varies by region (United Kingdom, DTI 2004, p. 5). Those in pharmaceuticals and health, electronics and ICT account for more than two-thirds of the R&D done by United States-based firms. German firms are concentrated in chemicals and engineering (64%), while Japanese firms are concentrated in electronics, ICT, engineering and chemicals (90%).

In sum, TNCs dominate global business R&D. A few countries, generally the largest R&D spenders, account for a major share of business R&D. Within those countries a relatively small number of enterprises dominate R&D activity. Most R&D is conducted by firms in the ICT, automotive and pharmaceutical industries.

B. R&D by TNCs is internationalizing

R&D is among the least internationalized segments of the TNCs' value chain; production, marketing and other functions have moved abroad much more quickly. However, some R&D has been undertaken abroad for a long time. In some form, R&D internationalization may date back to the earliest days of FDI; TNCs have always had to adapt technologies for selling in host countries, and in many cases some R&D has been necessary for this purpose (Safarian 1966, Brash 1966). There have also been cases of internationalization of basic research. In the years after the Second World War, Monsanto Chemicals (United States) expanded its centre for basic research in New Port, United Kingdom. Esso Petroleum Company's (United States) laboratories in the United Kingdom also performed basic research, and pioneered, among other inventions, a new synthetic lubricant for high-speed jet aircraft (Dunning 1958, p. 169). Firms from small developed home countries have conducted innovative ("asset-seeking") R&D abroad in other developed countries in order to tap other centres of innovation and overcome the constraints of their domestic economy (such as relatively small and/or specialized pools of knowledge and skills). Although the

internationalization of R&D has lagged behind that of other activities, the share of foreign R&D in the total is rising steadily.

R&D between countries can be linked in several ways, involving flows in both directions and several types of actors. Through FDI, TNCs can set up new foreign affiliates or acquire existing firms that are already conducting R&D in host countries. Greenfield investments are more common than acquisitions of local enterprises with R&D capacity, though exceptions exist in countries with strong local firms (Brockhoff 1998, van Boehmer 1995, Håkanson and Nobel 1993a). TNCs can also contract R&D to service providers in host countries without acquiring an ownership stake. In some activities (such as in software or pharmaceuticals in India), arm's length contracts with local enterprises or research laboratories are increasingly common. Internationalization of R&D can also take the form of contracts between two non-transnational firms that are located in different countries. Finally, enterprises in two or more countries can enter into alliances to conduct R&D jointly.

1. A growing share of TNCs' R&D is performed abroad

Despite difficulties in data gathering, the available evidence gives a reasonable picture of the R&D being carried out by TNCs abroad. Patterns vary significantly according to home countries, as illustrated by the United States, Sweden, Japan and Germany, but the trend is clear: a growing share of R&D is undertaken abroad.

In the United Kingdom, the United States and some smaller European countries, TNCs started internationalizing R&D on a large scale in the 1980s and this trend was accelerated in the 1990s.[4] R&D expenditures by majority-owned foreign affiliates of United States TNCs increased every year from 1994 to 2002 (except in 2001), reaching a record $21 billion in 2002. This level represented 13.3% of those TNCs' total R&D, up from 11.5% in 1994 (Moris 2005a).[5] In terms of employment, 16% of the R&D workers of United States TNCs were in foreign affiliates in 1999, up from 14% five years earlier (table IV.4).[6] Following the international trend, Swedish TNCs have also expanded their R&D activities abroad over time. Between 1995 and 2003, R&D spending by the largest Swedish TNCs increased modestly, from $5.1 billion to $5.8 billion (table IV.5),[7] but the share of R&D outside Sweden shot up from 22% to 43%.

In other home countries such as France, Germany, Italy, Japan and Spain, internationalization of R&D started much later, sometimes focusing more on licensing than on FDI.[8] The R&D expenditure of Japanese TNCs abroad rose from $1.9 billion to $3.3 billion during the period

Table IV.4. Global employment, R&D employment, and R&D expenditures of United States TNCs, by domestic and overseas components, 1994, 1999, 2002

Item	Total employment (Thousands)	R&D employment (Thousands)	R&D expenditures ($ million)	R&D expenditures per R&D employee ($)	R&D employment intensity[a] (%)
1994					
Total	24 273	727	103 451	142 338	3.0
Domestic operations (United States parent companies)	18 565	625	91 574	146 565	3.4
Overseas operations[b]	5 707	102	11 877	116 441	1.8
1999					
Total	30 773	770	144 435	187 505	2.5
Domestic operations (United States parent companies)	23 007	647	126 291	195 255	2.8
Overseas operations [b]	7 766	124	18 144	146 915	1.6
2002					
Total	..	..	159 119	..	..
Domestic operations (United States parent companies)	..	..	137 968	..	..
Overseas operations [b]	..	..	21 151	..	..

Source: UNCTAD, adapted from Moris 2005a, based on United States, National Science Foundation 2004.

[a] R&D employment intensity refers to the share of R&D employment in total employment.

[b] Majority-owned foreign affiliates.

Table IV.5. R&D expenditures of the 20 largest Swedish TNCs, 1995-2003
(Billions of dollars)

Item	1995	1997	1999	2001	2003
Total R&D expenditure by Swedish TNCs	5.07	6.06	5.45	5.86	5.81
R&D in Sweden	3.97	3.90	3.13	3.36	3.34
R&D abroad	1.11	2.17	2.31	2.50	2.47
In developing countries and economies in transition	0.03	0.07	0.10	0.15	0.18
Foreign share (%)	*22*	*36*	*42*	*43*	*43*

Source: UNCTAD, based on ITPS 2003 and 2005, and additional information provided by ITPS.

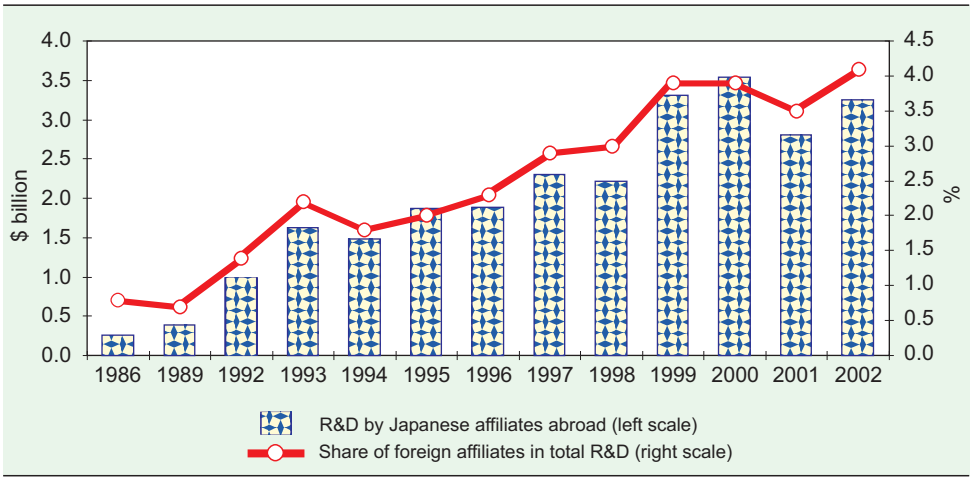
1995-2002 and its share in total Japanese R&D doubled from 2% to 4% (figure IV.2). Data from other home countries (e.g. Germany, box IV.1) are less comprehensive, although they are also indicative of the growing internationalization of R&D.

A number of surveys confirm the increased internationalization of R&D. One such survey founds that firms steadily increased their R&D spending abroad from 15% of their total R&D budget in 1995 to 22% in 2001 (Roberts 2001). Other recent studies also pointed to a trend towards increasing R&D abroad by TNCs from the Triad, especially European TNCs (Edler et al. 2002, von Zedtwitz and Gassmann 2002).[9]

A survey undertaken by UNCTAD from November 2004 to March 2005 of the world's largest R&D investors (box IV.2) suggests that the pace of R&D internationalization may be accelerating (section F). The average firm in the UNCTAD survey spent 28% of its R&D budget abroad in 2003,[10] including in-house expenditure by foreign affiliates and extramural spending on R&D contracted to other countries (figure IV.3). The share of R&D workers abroad in total R&D employees was similar.[11] Within this global picture, significant differences exist in the degree of internationa-lization of R&D of the various countries of origin (figure IV.3). Japanese and Korean TNCs displayed the lowest share of foreign R&D (15% and 2%, respectively; figure IV.3). North American TNCs were also below the average (24%). Conversely, European TNCs had high levels of R&D internationalization (41% on average).[12] Within Western Europe, companies from France, the Netherlands, Switzerland and the United Kingdom had the most internationalized R&D activities on average.

Due to the small size of the sample in the UNCTAD survey, only tentative conclusions can be drawn concerning industry-wide variations. The chemical and pharmaceutical industries were the most internationalized in terms of R&D (figure IV.4). The relatively low level of internationalization of R&D in the electronics and electrical industry (compared to chemicals and pharmaceuticals) partly reflects the strong presence of Japanese firms in that industry. Interestingly, the IT hardware industry's level of R&D internationalization was more

Figure IV.2. R&D expenditure by Japanese foreign affiliates abroad and its share in the total R&D spending of Japanese TNCs, 1986-2002
(Billions of dollars and per cent)



Source: UNCTAD, based on Japan, METI various issues.

Box IV.1. Foreign R&D affiliates of German TNCs

The number of foreign affiliates established or acquired abroad by German TNCs that carry out R&D as a primary or secondary business is small but growing, as is the outward FDI stock attributed to them (box table IV.1.1). Between 1995 and 2003 this stock rose from $43 million to $891 million, while employment by those affiliates grew from 2,000 to 11,000 during the same period. The R&D spending of German TNCs abroad rose by 130%, to $12 billion within the six-year period from 1995 to 2001.

Of the German TNCs, Siemens alone spent more than $6 billion on R&D in 2003 (table IV.1), accounting for about 7% of its sales (Sorg 2005). In 2004, of the 45,000 R&D employees of the company, 49% worked outside Germany. The number of R&D personnel in developing countries grew from 800 in 1994 (2% of the company total) to 2,700 (6%) in 2004, located in seven countries: Brazil, China, India, Malaysia, Mexico and South Africa (Sorg 2005).

A survey of 49 German TNCs accounting for two-thirds of Germany's privately funded R&D spending in that country, undertaken in 2000, concluded that internationalization of German R&D was the "phenomenon of the 1990s" (Ambos 2005, p. 401). In the 1990s, German firms established as many overseas R&D sites as in the previous 50 years combined. In 2000, the TNCs surveyed already had 134 R&D laboratories abroad (*idem*, p. 397). More than half of the foreign laboratories in pharmaceuticals, electronics and semiconductors spent more than 20 million per year, while those laboratories in the chemical and machinery industries generally had budgets of less than 5 million.

Box table IV.1.1. German R&D-related FDI abroad, 1995-2003

Year	FDI stock in R&D foreign affiliates abroad ($ million)	Number of R&D foreign affiliates	Employment of R&D foreign affiliates (Thousand)
1995	43.2	20	2
1996	83.8	25	2
1997	133.8	31	3
1998	199.6	55	5
1999	467.7	59	6
2000	647.7	89	9
2001	630.0	105	10
2002	934.3	73[a]	11
2003	891.4	78	11

Source: UNCTAD, based on Deutsche Bundesbank, unpublished data.

[a] Break in the series, not directly comparable with previous year.

Source: UNCTAD.

Box IV.2. Explanatory note on the UNCTAD survey on R&D internationalization

Between November 2004 and March 2005, UNCTAD conducted a survey aimed at establishing the current patterns of internationalization of R&D by the largest private R&D spenders. The population basis for the survey was the R&D Scoreboard published by the United Kingdom Department of Trade and Industry (DTI). Of the 700 top R&D spenders, UNCTAD contacted the leading 300 firms, which account for more than 85% of all R&D by the top 700. In addition, all companies in the DTI Scoreboard that were from developing, South-East European and CIS economies were invited to participate in the survey even if they fell outside the top 300. This brought the number of questionnaires sent out to 316.

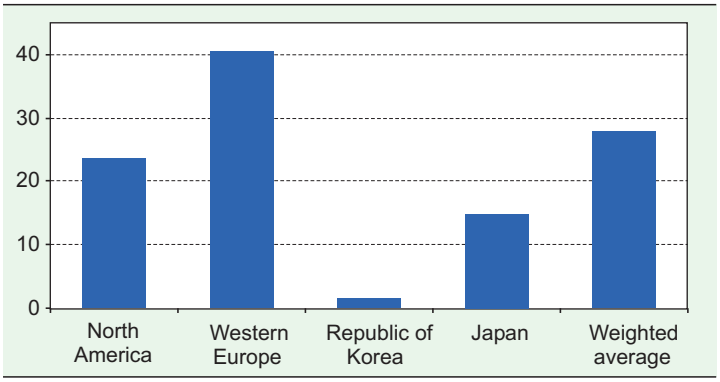
The response rate was 22% of the sample or 68 companies. The relatively low response rate was due to the fact that many firms are unwilling to participate in such surveys as they consider information concerning their R&D activities too strategically sensitive to be disclosed.

Some potential shortcomings should be borne in mind. First, the reporting of R&D may not always be done in the same way due to different notions of what R&D entails. Second, some respondents may have omitted smaller R&D activities. Third, the United States is underrepresented, although some of the largest United States R&D investors participated in the survey.

The industrial composition of the sample is broadly similar to that of the DTI R&D Scoreboard: IT hardware, automotive, pharmaceuticals, electronic and electrical and chemicals are 5 of the 6 main R&D investing industries. The software and computer services industry was underrepresented, mainly due to a low response rate by United States companies.

Source: UNCTAD.

Figure IV.3. Degree of R&D internationalization by home region or country in the UNCTAD survey, 2004-2005
(Per cent)



Source: UNCTAD survey.

pronounced in terms of R&D employees abroad than in terms of expenditure – possibly indicating that R&D abroad is undertaken with a view to reducing labour costs. The opposite was the case for the automotive industry – possibly suggesting the greater importance in that industry of market-seeking motives for foreign R&D.

2. The growing role of foreign affiliates in host-country R&D

The increasing internationalization of R&D by TNCs is also reflected in the growing role played by foreign affiliates in the R&D activities of many countries. In 1993, the R&D expenditure of foreign affiliates in host countries worldwide – the operations equivalent of inward FDI in R&D – amounted to about $29 billion (i.e. 10% of global business enterprise spending on R&D) (figure IV.5). Within a decade, by 2002, that spending had more than doubled to $67 billion or 16% of global business R&D.[13] This growth was more than twice as fast as that of global spending by enterprises on R&D, spending that grew by about 49% over the same period.

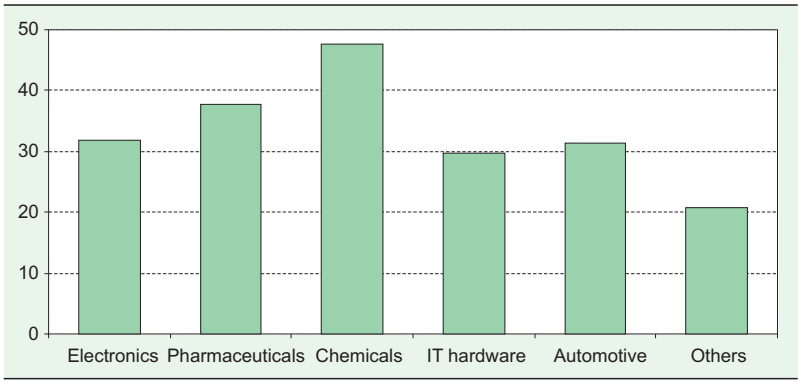
The share of foreign affiliates in host-country R&D varies by country. In 2003, it exceeded 50% in Ireland, Hungary and Singapore (figure IV.6), and 40% in five other countries (Brazil, the Czech Republic, Sweden, the United Kingdom and Australia in descending order). Conversely, it remained under 10% in the Republic of Korea, Japan, India,[14] Chile and Greece.

The share of foreign affiliates in the business R&D of developed countries is close to the world average and has been growing gradually, from 11% in 1996 to 16% in 2002 (annex table A.IV.1). In the four new EU members for which data were available, the share of foreign affiliates was already above the world average in 1996 (17%) and increased further, to 41%, by 2002.[15] In the developing countries for which data are available, the share of foreign affiliates rose faster than in developed countries (from 2% in 1996 to close to 18% in 2002, annex table A.IV.1).

In fact, more than two-thirds of the 30 countries for which data were available experienced a rise in the share of foreign affiliates in business R&D after 1995, and this rise was larger in developing countries (figure IV.6).[16] In the new EU member countries, as well as in Sweden and the United Kingdom, the share of foreign affiliates also rose rapidly as local high-technology firms were taken over by foreign TNCs[17] and new R&D facilities were located in these economies. The high share of foreign affiliates in the new EU member countries reflects not only the rising degree of penetration by foreign TNCs but also the low level of domestic R&D efforts (both total and business R&D; see also chapter III).

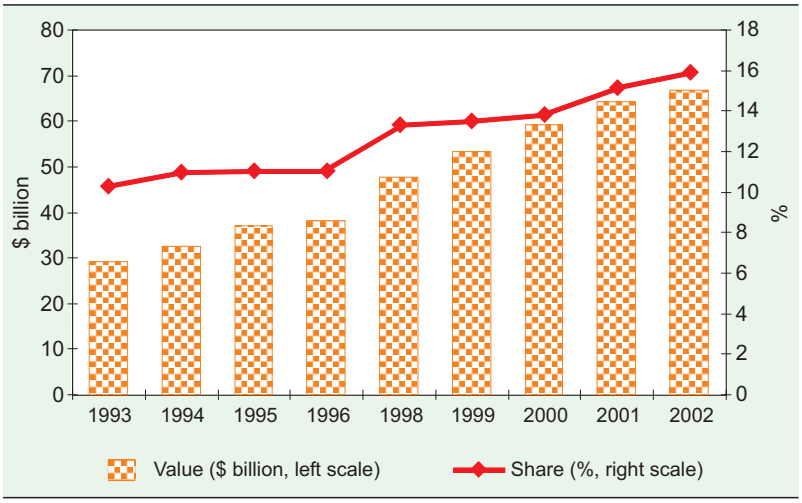
The large *number* of majority-owned foreign affiliates with R&D as their main activity (2,600 in 2004)[18] reflects the spread of the R&D activities that TNCs are conducting outside their

Figure IV.4. Degree of R&D internationalization by industry, 2004-2005
(Per cent)



Source: UNCTAD survey.

Figure IV.5. R&D expenditure by foreign affiliates, based on a sample of 30 economies, value and share in business R&D, 1993-2002
(Billions of dollars and per cent)



Source: UNCTAD, based on annex table A.IV.1.

home base (figure IV.7). Close to 70% of these affiliates are located in the Triad, but the map also indicates the presence of such activities in various developing economies, especially in Asia.

3. Growing use of strategic alliances

Another indication of a rise in the internationalization of R&D is the expansion of cooperative arrangements, such as strategic alliances, in R&D (Dunning and Narula 2005, p. 130). Since the 1980s firms have increasingly sought to undertake R&D activities through collaborative efforts, as evidenced by information from the MERIT/CATI database,[19] which contains data on nearly 10,000 strategic technology alliances of 3,500 parent companies for the period 1960-1998 (Hagedoorn 2002). Growth was steady in the early years of this period and accelerated from the 1980s onwards. Although collaborative activity in R&D is not a new practice – economic units have collaborated for decades – it has evolved incontestably towards direct strategic uses (Narula 2003, p. 110). The relative share of non-equity (contractual) partnerships in the total number of strategic alliances increased considerably over the same period. The geography of strategic alliances was dominated by intra-North American partnerships, followed by EU-North America and intra-EU alliances (Hagedoorn 2002).

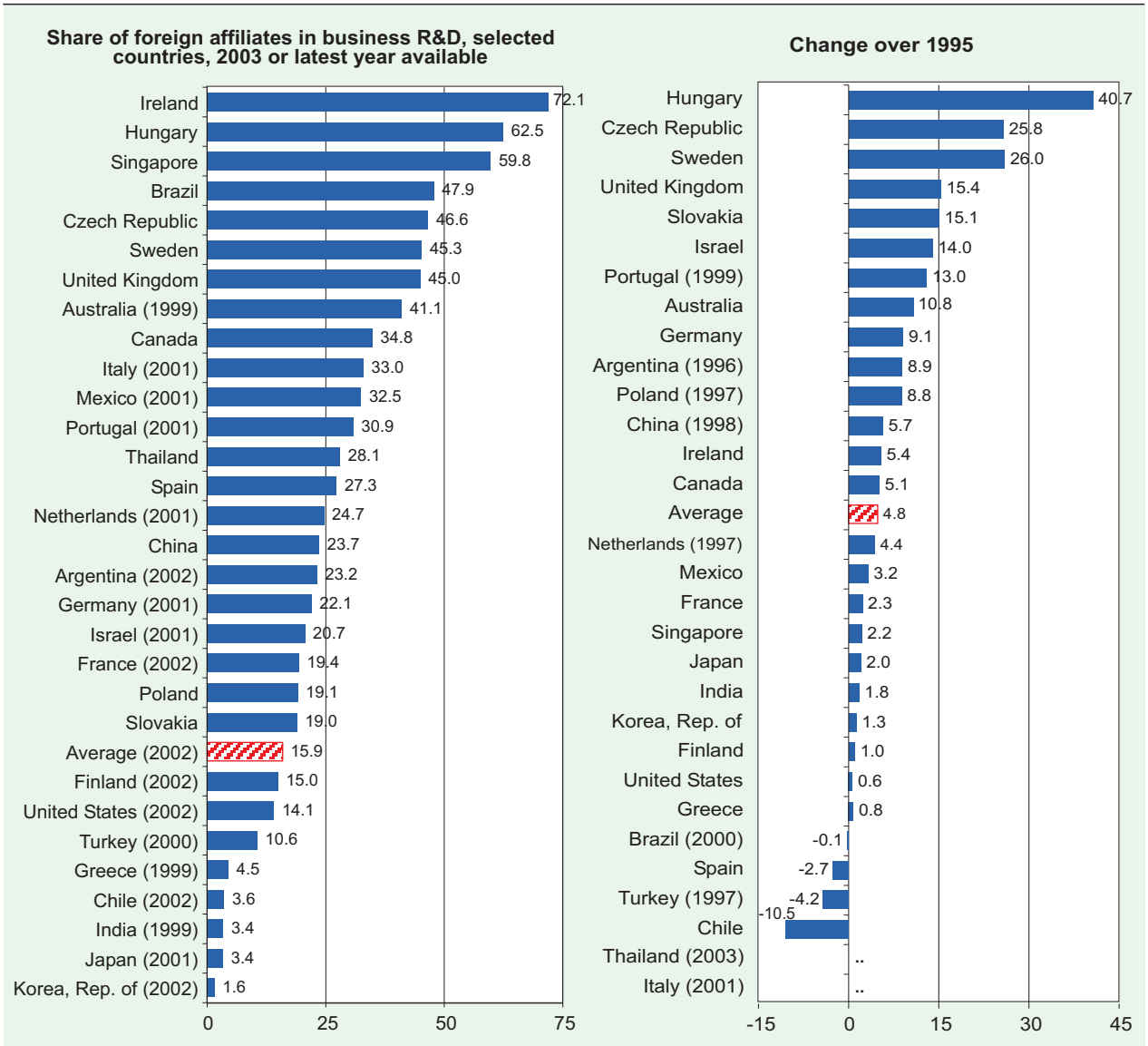
Data for a more recent period (1991-2001) show a doubling of new international technology alliances, from 339 to 602, and a growing dominance of non-equity forms within alliances.[20] Indeed, while the number of non-equity alliances increased from 265 in 1991 to 545 in 2001 (i.e. in more than 90% of the alliances) the number of equity-based partnerships declined from 74 to 57. United States firms continued to participate in a large majority of strategic alliances, although their share in the total of such alliances declined from 80% in 1991 to 73% in 2001. At the same time the participation of non-Triad firms increased from 4% to 14%.

Between 1991 and 2001, the industry composition of alliances shifted strongly from information technologies (whose share dropped from 54% to 28%) to pharmaceuticals and biotechnology (whose share increased from 11% to 58%). In the latter, there is a strong incentive for TNCs to form strategic alliances with other companies in the industry as well as with academic institutions, as no single company could possibly develop excellence in all the areas of research that may be required to develop a new drug. Moreover, there are strong pressures on pharmaceutical companies to reduce drug development costs and to share the risks involved.

C. The emergence of developing economies as locations for TNCs' R&D

Developed countries remain the main host locations of foreign R&D activities by TNCs,[21] but there is a clear trend towards locating more R&D activities to developing economies, South-East Europe and the CIS. This is confirmed by available national statistics as well as by corporate surveys and case studies. The kind of R&D being undertaken by TNCs in developing

Figure IV.6. Trends in R&D spending by foreign affiliates, selected economies, 1995-2003
(Per cent)



Source: UNCTAD's calculations, based on national sources and data provided from the OECD AFA database.

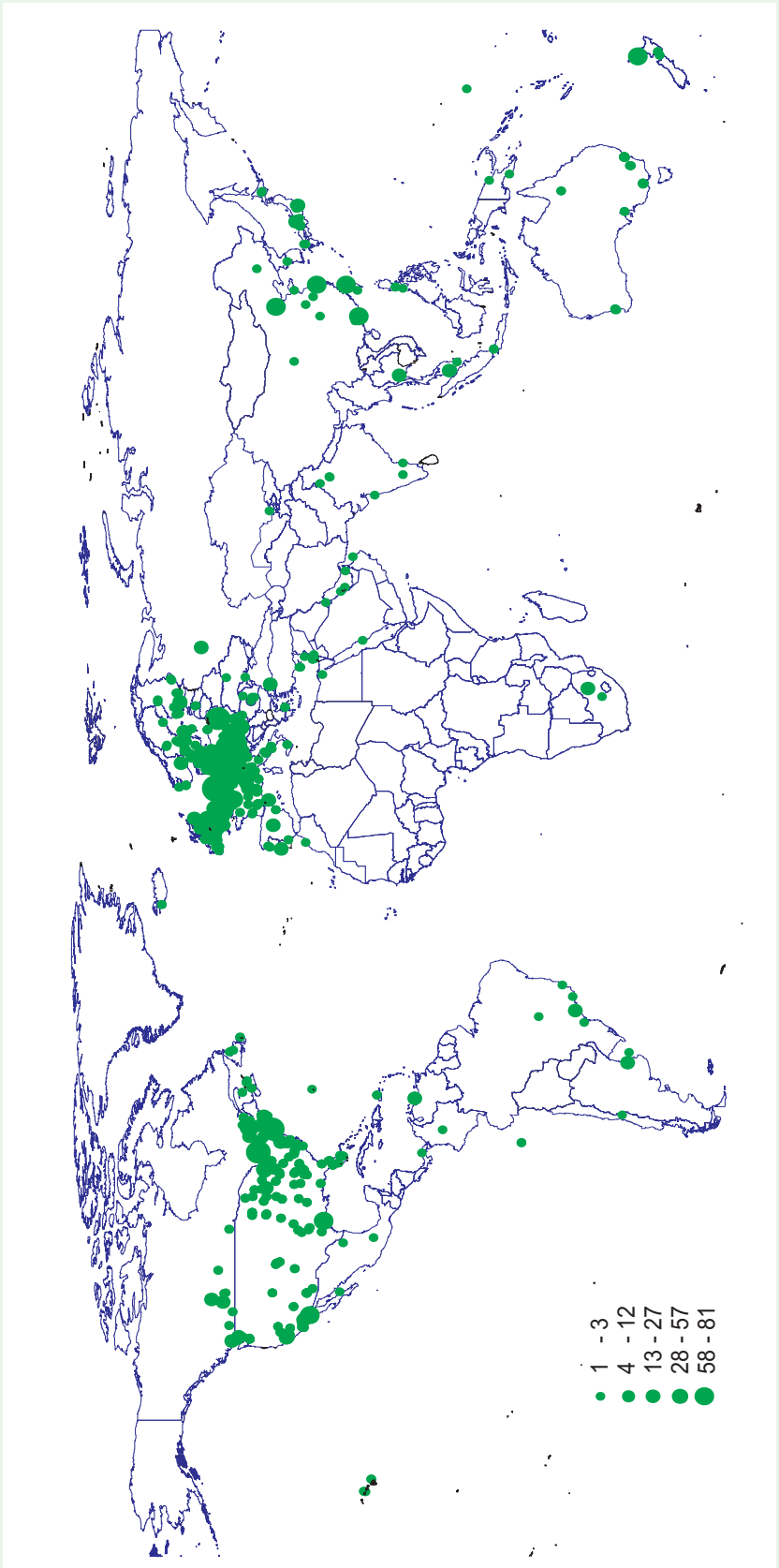
Note: In Argentina, Chile, Israel, the Republic of Korea and Mexico, the R&D expenditure of United States-owned affiliates has been used as a proxy for the R&D spending of all foreign affiliates. In India, the share of foreign affiliates in total R&D spending has been used as a proxy for their share in business R&D spending.

countries is also changing. While it has traditionally involved mainly product or process adaptation to meet local market demands, recent developments suggest that some developing, South-East European and CIS markets are emerging as key nodes in the global R&D systems of TNCs. At the same time, the extent to which developing countries participate in these systems varies considerably, and large parts of the developing world remain de-linked.

1. TNCs are expanding R&D to developing locations

Data on overseas R&D by TNCs from the United States show a decline in the share of some developed countries during the past decade.[22] In 1994 developed countries accounted for 92% of overseas R&D expenditures by United States TNCs (table IV.6), but by 2002 their share had dropped by 8 percentage points due to a

Figure IV.7. Worldwide location of majority-owned foreign affiliates engaged in R&D, 2004



Source: UNCTAD, based on the *Who Owns Whom* database (Dun & Bradstreet).
Note: On the basis of 2,603 majority-owned foreign affiliates engaged in R&D.

strong decline in the shares of the EU (by 11 percentage points) and Japan (by 3 percentage points). Not all developed economies have been losing ground, however. Rapid growth was observed in Canada and Israel and there was some growth in Switzerland.

The shares lost by developed countries were picked up by developing economies, almost exclusively in Asia. China, Singapore, Hong Kong (China), Malaysia and the Republic of Korea were among the main gainers of R&D shares. As a result, the role of developing countries as a whole increased, from 7.6% to 13.5%.

Table IV.6. R&D expenditure abroad by majority-owned foreign affiliates of United States parent companies, by selected region/country, 1994–2002
(Millions of dollars)

Region/economy	Year									Share of total (%)	
	1994	1995	1996	1997	1998	1999	2000	2001	2002[a]	1994	2002
Total	**11 877**	**12 582**	**14 039**	**14 593**	**14 664**	**18 144**	**20 457**	**19 702**	**21 151**	**100.0**	**100.0**
Developed economies	**10 975**	**11 891**	**13 152**	**13 510**	**13 545**	**16 113**	**17 791**	**16 720**	**17 844**	**92.4**	**84.4**
of which:											
Canada	836	1 068	1 563	1 823	1 750	1 681	2 332	2 131	2 345	7.0	11.1
EU[c]	8 271	8 852	9 386	9 691	10 058	11 900	12 472	11 578	[b]	69.6	58.8
Switzerland	191	242	190	230	223	231	286	392	405	1.6	1.9
Israel	96	97	169	208	141	389	630	726	889	0.8	4.2
Japan	1 130	1 286	1 333	1 089	962	1 523	1 630	1 507	1 433	9.5	6.8
Australia	230	287	409	369	290	294	349	286	329	1.9	1.6
New Zealand	7	9	16	18	15	9	8	10	6	0.1	-
Developing economies	**902**	**691**	**886**	**1 082**	**1 119**	**2 031**	**2 637**	**2 982**	**2 855**	**7.6**	**13.5**
Developing Asia	**408**	**283**	**318**	**393**	**336**	**1 400**	**1 949**	**2 391**	**2 113**	**3.4**	**10.0**
of which:											
China	7	13	25	35	52	319	506	[b]	646	0.1	3.1
Hong Kong, China	51	55	38	82	66	214	[b]	289	[b]	0.4	[b]
India	5	5	9	22	23	20	[b]	[b]	80	-	0.4
Indonesia	5	9	6	5	4	1	2	3	3	-	-
Korea, Republic of	17	29	34	41	29	101	143	157	167	0.1	0.8
Malaysia	27	21	23	32	30	161	218	[b]	[b]	0.2	[b]
Philippines	14	23	14	12	10	31	40	48	50	0.1	0.2
Singapore	167	63	88	73	62	426	551	755	589	1.4	2.8
Taiwan Province of China	110	61	75	84	55	122	143	139	70	0.9	0.3
Thailand	3	5	5	5	4	7	13	18	22	-	0.1
Latin America and the Caribbean	**477**	**389**	**546**	**663**	**748**	**613**	**663**	**562**	**[b]**	**4.0**	**3.2[e]**
of which:											
Argentina	21	22	42	43	56	26	38	43	24	0.2	0.1
Brazil	238	249	346	437	446	288	253	199	306	2.0	1.4
Chile	2	15	6	7	6	4	11	8	6	-	-
Colombia	8	9	9	12	11	6	10	11	10	0.1	0.1
Costa Rica	2	2	2	4	6	2	[b]	4	7	-	-
Mexico	183	58	121	126	191	238	303	248	284	1.5	1.3
Venezuela	17	25	9	11	14	40	22	24	42	0.1	0.2
West Asia and North Africa	**15**	**19**	**21**	**26**	**35**	**18**	**25**	**29**	**[b]**	**0.1**	**[b]**
Sub-Saharan Africa	**15**	**19**	**21**	**26**	**35**	**18**	**25**	**29**	**[b]**	**0.1**	**[b]**
of which:											
South Africa	14	17	18	22	30	14	21	24	[b]	0.1	0.1
Economies in transition[d]	**5**	**18**	**36**	**48**	**79**	**54**	**83**	**38**	**68**	**-**	**0.3**

Source: UNCTAD, adapted from Moris 2005a, based on data from United States Department of Commerce, Bureau of Economic Analysis, *Survey of U.S. Direct Investment Abroad*, www.bea.gov/bea.

[a] Estimates for 2002 are preliminary.
[b] Withheld to avoid disclosing operations of individual companies. Note that due to undisclosed data, shares do not add up to 100%.
[c] EU covers 12 countries for 1994 and 15 countries thereafter.
[d] Including new EU members.
[e] Based on data for countries listed below.

Note: Data are for majority-owned foreign affiliates of United States parent companies. Majority-owned affiliates are those in which the combined ownership of all United States parents is more than 50%.

Expenditures on R&D by affiliates of United States TNCs in developing economies are concentrated mostly in five countries: China, Singapore, Brazil, Mexico and the Republic of Korea in that order. They accounted for 70% of the total R&D expenditure of United States TNCs in developing countries in 2002. In contrast, Taiwan Province of China and India attracted relatively small amounts of their R&D. India, a major site for foreign R&D in recent years, accounted for only a small share of R&D spending by United States TNCs until 2002 according to official data, although more recently this share has risen.

In Latin America and the Caribbean, Brazil and Mexico have accounted for around 80% of R&D expenditures by United States TNCs in the region since 1994. In absolute terms, their growth has been modest compared to that in the major Asian economies, and the relative importance of Latin America and the Caribbean in the R&D of United States TNCs has fallen. Venezuela is a relatively significant host for United States TNCs' R&D, much of it concentrated in the petroleum industry. South Africa accounted for virtually all of the R&D by United States TNCs in Africa over the same period.

The rising share of developing economies is also noticeable in R&D employment by United States TNCs. Their share grew faster than that of developed countries over the period 1994-1999 although the EU still dominates. In particular, the share of R&D employment in developing Asia doubled from 4.1% in 1994 to 8.1% in 1999 (United States, NSF 2004). This figure is likely to increase further judging from data on R&D expenditures, which shows the share of developing Asia rose from 7.7% to 10% between 1999 and 2002 (table IV.6).

In 1999, the latest year for which R&D employment data are available,[23] the number of scientists and engineers employed full time for carrying out R&D for United States TNCs reached 770,300 (i.e. 3% of the total workforce of these firms in 1999). About 123,500 of them – or 16% – worked abroad in majority-owned foreign affiliates of those TNCs (table IV.7). Close to 16% of these employees abroad were employed in developing countries.

The R&D intensity of employment still remains low in developing economies compared to the developed countries. Among the developing economies, only Singapore and the Republic of Korea reached an R&D intensity similar to that of developed countries (table IV.7). R&D expenditures per R&D employee in the foreign affiliates of United States TNCs reached $146,915 in 1999, 26% up from 1994. Between 1994 and 1999 R&D expenditures per R&D employee increased at double digits in all developing host regions except Latin America.

The selection of developing countries as locations for R&D is gaining momentum in Europe as well. In the foreign R&D activities of Swedish TNCs (table IV.5), the share of developing countries and economies in transition (including the new EU members) increased rapidly, from 2.7% in 1995 to 7.2% in 2003. A survey of 1,554 German enterprises conducted in 2005 by the Deutsche Industrie- und Handelskammertag, the umbrella organization for German chambers of commerce, found that while foreign R&D units were most frequently located in other EU States, about a third of respondents conducted R&D in new EU member countries, South-East Europe or the CIS and 28% in Asia (DIHK 2005b).

In Japan, surveys carried out by the Japan Bank for International Cooperation (JBIC) confirm the trend that Japanese companies are changing their R&D strategies to become more international (table IV.8). The overall number of "R&D bases"[24] set up by the firms covered in the surveys increased by 70%, to 310, between 2000 and 2004, and that of "R&D bases" in developing countries more than tripled, to 134. The increase was most pronounced for China: its share of all R&D units rose from 7% to 22% between 2000 and 2004.

Official statistics do not necessarily capture the rise of developing-country locations over the past 2 to 3 years. Recent company surveys, however, indicate that the trend has gained momentum. In a 2004 survey, 70% of the responding firms stated that they already undertook R&D abroad, and that more R&D had recently been allocated to locations outside the developed countries (EIU 2004a). Similarly, recent information on new greenfield and expansion FDI projects involving R&D indicates a surge of developing destinations and service-related R&D (OCO Consulting, LOCOmonitor database).[25] Of the 1,773 FDI projects in R&D worldwide for which information has been collected for the period 2002–2004, the majority (1,095) were undertaken in developing economies, South-East Europe and the CIS. Developing Asia and Oceania alone accounted

Table IV.7. R&D employment by majority-owned foreign affiliates of United States TNCs by region/economy, 1999
(Thousand employees and per cent)

Region/economy	Total employment (Thousand)	R&D employment (Thousand)	R&D intensity (%)	Region/economy	Total employment (Thousand)	R&D employment (Thousand)	R&D intensity (%)
All economies	**7 765.8**	**123.5**	**1.6**	Thailand	102.3	0.1	0.1
Developed economies	**4 378.9**	**96.2**	**2.2**	**Latin America and the Caribbean**	**1 536.4**	**9.0**	**0.6**
of which:				of which:			
Canada	1 004.2	7.9	0.8	Argentina	93.8	0.3	0.3
European Union	3 167.4	80.8	2.6	Brazil	348.8	5.4	1.5
Japan	207.3	7.5	3.6	Chile	43.6	[a]	[b]
Israel	33.0	2.6	7.9	Colombia	43.9	0.1	0.2
Developing economies	**2 702.7**	**19.2**	**0.7**	Costa Rica	25.3	[a]	[b]
Developing Asia	**1 021.1**	**10.0**	**1.0**	Mexico	780.8	2.7	0.3
of which:				Venezuela	63.2	0.4	0.6
China	252.4	2	0.8				
Hong Kong (China)	93.8	1.2	1.3	**West Asia and North Africa**	**19.2**	**-**	**-**
India	62.2	0.2	0.3				
Indonesia	61.6	[a]	[b]	**Sub-Saharan Africa**	**126**	**0.2**	**0.2**
Korea, Republic of	46.1	1.0	2.2	of which:			
Malaysia	119.1	[a]	[b]	South Africa	55	0.1	0.2
Philippines	78.1	0.5	0.6				
Singapore	114.8	2.6	2.3	**Unspecified**	**684.2**	**8.1**	**1.2**
Taiwan Province of China	71.3	0.9	1.3				

Source: United States Bureau of Economic Analysis, *Survey of U.S. Direct Investment Abroad,* annual series, www.bea.gov/bea.

[a] Less than 50 employees.

[b] Withheld to avoid disclosing operations of individual companies.

Note: R&D employment intensity is R&D employment as a percentage of total employment. EU comprises the 15 members in 1999.

for close to half of the world total (861 projects). These data also suggest that the majority of new jobs created in greenfield FDI projects related to R&D also went to developing countries, mostly to India and China.

More than 90% of the above-mentioned new FDI projects involving R&D were initiated by TNCs from developed countries. The United States was the top source country, accounting for almost half of the world total, followed by the EU-15 and Japan. However, developing-country TNCs are also becoming more active in this area (see also section E). Of the 160 projects carried out by developing-economy TNCs, 151 originated in Asia, mainly in India, the Republic of Korea, Taiwan Province of China, China and Singapore, in that order.

A matrix of the home and host countries of R&D projects (table IV.9) reveals that the "traditional" pattern of developed-country

Table IV.8. R&D bases of Japanese manufacturing companies, by host region, 2000-2004
(Number of R&D bases)

Host region	2000	2001	2002	2003	2004
NIEs	16	15	30	21	25
ASEAN-4	10	18	21	18	29
China	13	19	28	29	67
Other Asia	2	2	2	3	6
North America	88	84	92	88	108
Latin America	2	1	1	0	4
EU-15	44	47	70	48	60
Central and Eastern Europe	1	1	3	3	3
South-East Asia and Oceania	-	4	6	6	8
Other countries	1	2	3	-	-
Total R&D bases	177	193	256	216	310

Source: UNCTAD, based on JBIC (various years), *Survey Report on Overseas Business Operations by Japanese Manufacturing Companies* (Tokyo: JBIC).

Note: ASEAN-4 consists of Indonesia, Malaysia, the Philippines and Thailand.

NIE (newly industrializing economies) consists of Hong Kong (China), the Republic of Korea, Singapore and Taiwan Province of China.

TNCs investing in other developed countries (well documented and analysed in the literature; von Zedtwitz 2005) accounted for less than one-third of the new R&D projects in 2002-2004. Meanwhile, the "modern" type of R&D expansion (developed-country TNCs investing in developing countries, South-East Europe and the CIS) has become significant (almost three-fifths of the cases). Examples include Intel's R&D laboratories in China and India (box IV.3), IBM's R&D in India, Microsoft's research laboratory in China and Fujitsu's development centre in Malaysia.

In turn, the other patterns of R&D-related FDI ("catch-up", whereby TNCs from developing economies conduct R&D in developed countries with the aim of catching up with developed-country TNCs; and "expansionary", whereby a TNC from a

Table IV.9. Greenfield FDI projects in R&D, 2002-2004
(Number of projects)

	Host economy			
Home economy	Developed	Developing	South-East Europe and CIS	Total
Developed	*"Traditional"*	*"Modern"*		
	612	953	40	1 605
Developing	*"Catch-up"*	*"Expansionary"*		
	63	97	2	162
South-East	*"Catch-up"*	*"Expansionary"*		
Europe and CIS	3	3	-	6
Total	678	1 053	42	1 773

Source: UNCTAD's calculations, based on the LOCOmonitor database (classification draws on von Zedtwitz 2005).

Box IV.3. Intel's R&D network in developing countries

Intel has over 20,000 R&D employees located in more than 30 countries. Some of the facilities are owned by the parent firm while others are managed in collaboration with universities or through venture-capital investments in technology-intensive companies.

Intel's R&D investments in developing and South-East European and CIS economies, especially in China, India and the Russian Federation, are growing faster than elsewhere. That expansion is motivated by the availability of an educated and skilled workforce with specific competencies in relevant areas. In these countries, Intel owns laboratories that conduct key research in a variety of fields; it has also signed a series of collaboration agreements with universities.

Intel China Research Centre (ICRC) in Beijing was established in 1998 as the company's first research lab in the Asia-Oceania region. ICRC has conducted applied research in the areas of human computer interface, computer architecture, future workloads and compilers and runtime. In early 2005, it had a staff of 75 researchers, most of whom hold a PhD or an MSc from Chinese universities. Among the research innovations that have emerged from ICRC are Open Research Compiler, developed jointly with the Chinese Academy of Science; Audio Visual Speech Recognition, a system using computer vision to assist speech recognition; and Microphone Array and audio signal processing technology. A second Chinese R&D laboratory with over 150 employees is operating in Shanghai developing software for Intel.

The Intel India Design Centre in Bangalore employs more than 800 employees and delivers software solutions to the company. In comparison, the Nizhny Novgorod (Russian Federation) software development centre is home to 340 specialists and engineers who are developing software tools and applications for Intel.

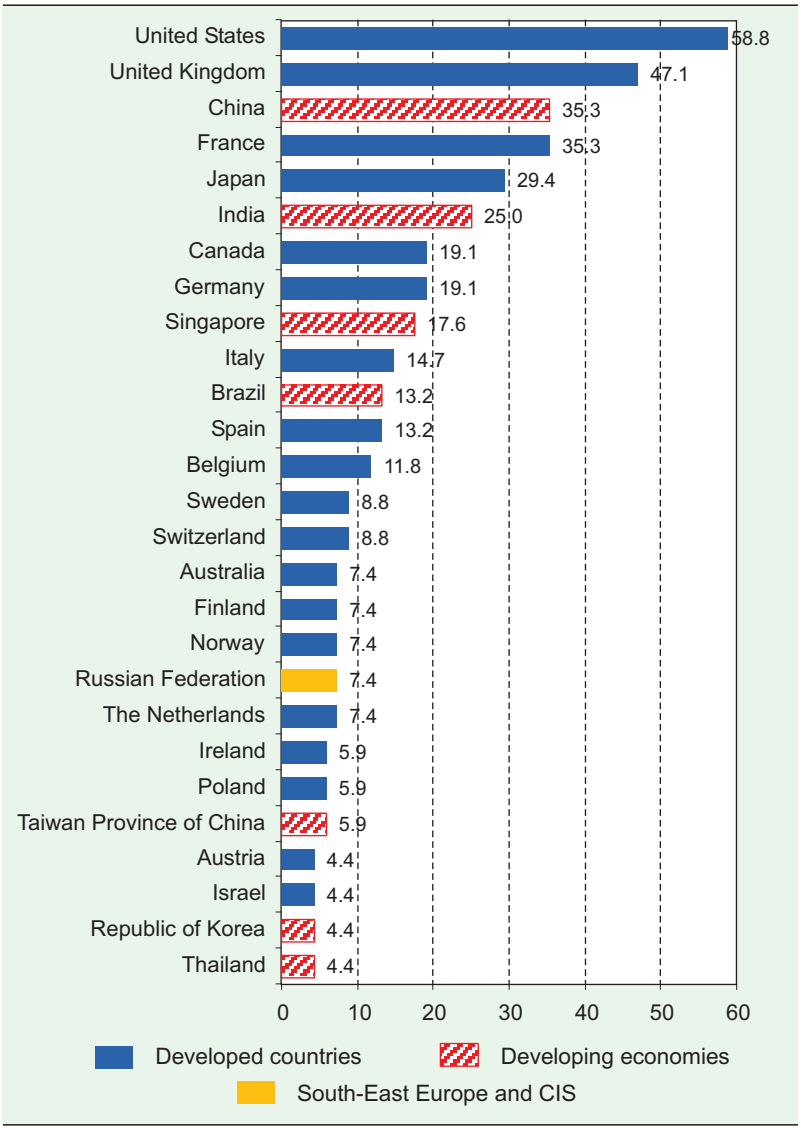
Cooperation with universities abroad is an important aspect of Intel's global strategy. The Intel Research Council, an internal group of technical experts, awards university research grants worldwide for projects in key areas. A final vector of Intel's global strategy is Intel Capital, Intel's strategic investment programme. Its mission is to make and manage financially attractive investments that support Intel's strategic objectives. Its overseas presence grew from less than 5% of the value of the deals in 1998 to about 40% in 2003. Of these overseas investments, about half were in companies based in Asia (including Japan) and the rest in Europe, Israel and Latin America.

Source: UNCTAD, based on information provided by Intel in March 2005.

developing country invests in R&D in another developing country to support either second-generation technology transfers or other local business activities) together accounted for less than one-tenth of the total.[26] Samsung's (Republic of Korea) laboratories in Europe, and Acer's (Taiwan Province of China) laboratories in the United States are examples of the "catch-up" type of R&D-related FDI, while Acer's R&D laboratory in China and Huawei's R&D centre in Bangalore illustrate the "expansionary" type (see also section E).

UNCTAD's survey of the largest R&D spenders among TNCs (referred to above) confirms the growing importance of developing-country locations. Although the majority of the R&D conducted abroad is in other developed countries (the United States and the United Kingdom being the two top destinations), a number of developing countries were also mentioned by the 68 respondents. The current location of their foreign R&D efforts in developing countries was reported as being, among others, China (3rd global destination), India (6th), Singapore (9th) and Brazil (11th) (figure IV.8).[27] Also, notably, a large number of other developing-country R&D locations (14 economies) were indicated by at least one of the

Figure IV.8. Current foreign locations of R&D in the UNCTAD survey, 2004
(Per cent)



Source: UNCTAD survey.

Note: Countries mentioned by two respondents include: the Czech Republic, Hungary, Indonesia, Malaysia, Mexico and Portugal. Economies mentioned by one respondent include: Argentina, Bulgaria, Denmark, Estonia, Greece, Hong Kong (China), Morocco, the Philippines, Saudi Arabia, Slovakia, South Africa, Turkey and Viet Nam.

respondents. In South-East Europe and the CIS, the Russian Federation and Bulgaria were the only target economies mentioned.[28]

The companies responding to the UNCTAD survey also answered questions related to international non-equity collaboration in the area of R&D. The most frequently mentioned location for such arrangements was again the United States, followed by the United Kingdom. China was in third place ahead of Germany, France and Japan. A roughly equal share of the responding companies had R&D collaboration with counterparts in the Russian Federation and in India. Other developing and South-East European and CIS economies mentioned included: Argentina, Brazil, Mexico, Morocco, Singapore, Taiwan Province of China and Tunisia. A recent survey of 104 TNCs (EIU 2004a) has also found that Europe and Asia are the most common locations of R&D (indicated by 34% and 30% of the respondents), followed by North America (17%).[29]

2. Foreign affiliates in patenting by developing economies

The role of TNCs in the R&D activities of a country can also be gauged from measures related to the output of R&D activities. The analysis in this section draws on information from the United States Patent and Trademark Office (USPTO).[30] As noted above (chapter III), the number of *patent applications* to the USPTO from developing economies and countries in South-East Europe and the CIS has risen dramatically in recent years (albeit from a low base), primarily due to increased research activities in Asia and Oceania (annex table A.III.3). A detailed analysis suggests that foreign companies play an important role in the patentable outputs of these countries, with some important exceptions.

In order to assess the role of TNCs it is necessary to distinguish between the "inventor" and the "assignee" of a patent. According to the patent law of the United States, the *applicant* in a patent application must always be the inventor. Therefore, patents are *granted* to an inventor or a group of inventors, but not to institutions. However, many patents or patent applications are *assigned* (i.e. transferred) to those other than the inventor(s), usually to institutions. The assignee then becomes the legal owner of the patent.[31]

The number of USPTO patents *granted* to inventors resident in the economies included in table IV.10 increased more than fourfold between 1993 and 2003.[32] The table shows that for the period of 2001-2003, many patents granted to inventors resident in these economies were *assigned* to entities (typically TNCs) based in other countries. Patents assigned to foreigners may be the output of R&D outsourced by foreign TNCs to scientists in the listed economies or the output of R&D conducted by inventors employed by foreign affiliates in these economies. Thus the share of patents assigned to foreigners in the total number of patents granted to residents in a country can be seen as an indicator of the role of foreign TNCs in the innovation activities of the economies (e.g. Guellec and van Pottelsberghe de la Potterie 2001, 2004b).

By this measure, foreign companies played a very small role in the patents granted by the USPTO to inventors in the Republic of Korea and Taiwan Province of China during the period 2001-2003; only 4% of them were assigned to foreigners (table IV.10). However, in most other economies in the table — including Brazil, China, India and the Russian Federation — a large share of the patents were assigned to foreign entities — ranging from 25% in Saudi Arabia to 86% in Kenya.[33]

While TNCs thus appear to own a large share of USPTO patents granted to inventors in developing economies and South-East Europe and the CIS, the number of patents that are owned by foreign affiliates located in these economies is generally small. USPTO data show that most patents *assigned* during the period 2001-2003 to entities in the economies listed in table IV.11 were owned by domestic enterprises or, in some economies, by public institutions, but only rarely by foreign affiliates. Only in Bulgaria and Brazil did foreign affiliates account for more than 20% of all patents assigned.[34] In India and Cuba, public research institutions accounted for the largest shares (68% and 84% respectively) of those countries' totals.[35] Public research institutions in Singapore, the Russian Federation and Ukraine also receive a significant proportion of the patents assigned by the USPTO.

Table IV.10. United States Patent and Trademark Office patents granted to residents of selected developing economies and countries in South-East Europe and CIS, 2001-2003
(Number of patents and per cent)

Region/economy	Patents granted to residents (a)	Patents assigned to foreign institutions (b)	The share of (b) in (a) (%)
Africa			
South Africa	428	126	29
Egypt	32	21	66
Kenya	21	18	86
Asia and Oceania			
Taiwan Province of China	20 414	889	4
Republic of Korea	12 195	482	4
China	1 543	979	63
Singapore	1 485	669	45
Hong Kong (China)	2 069	692	33
India	1 022	409	40
Malaysia	281	207	74
Turkey	101	71	70
Thailand	208	116	56
Philippines	108	92	85
Saudi Arabia	64	16	25
Indonesia	108	69	64
Latin America and the Caribbean			
Brazil	524	220	42
Mexico	409	215	53
Argentina	202	70	35
Bahamas	47	36	77
Bermuda	22	12	55
Cuba	21	-	-
Chile	54	27	50
South-East Europe and CIS			
Russian Federation	956	654	68
Ukraine	131	98	75
Bulgaria	34	16	47

Source: UNCTAD, based on information from the USPTO patent database.

Note: The patent count in tables in this section includes all types of patents, i.e. utility, design as well as plant patents. Column (a) lists the number of patents where at least one inventor is from a developing economy or a country in South-East Europe or the CIS. Column (b) lists the number of patents in (a) that are assigned to foreigners (usually institutions).

In sum, with the important exceptions of the Republic of Korea and Taiwan Province of China, foreign companies play a significant role in the innovation activities of those developing economies and countries in South-East Europe and the CIS that have expanded their patenting activities in the United States during the past decade. A large share of all patents granted to inventors in these economies is assigned to owners abroad, notably TNCs. However, since few foreign affiliates are owners of patents in these countries it would appear that TNCs tend to centralize the ownership of patents at headquarters.

D. Features of R&D undertaken in developing, South-East European and CIS markets

1. Industry composition of R&D by TNCs in developing countries

The industry composition of R&D by foreign affiliates differs by region and economy. For instance, three-quarters of R&D by United States affiliates located in Asia (excluding Japan)

Table IV.11. United States Patent and Trademark Office patents assigned to institutions in selected economies by the type of assignee, 2001-2003
(Number of patents)

Region/economy	Domestic firms	Foreign affiliates	Public institutions	Total
Africa				
South Africa	153	7	7	167
Egypt	3	-	4	7
Asia and Oceania				
Taiwan Province of China	11 621	118	947	12 686
Republic of Korea	9 829	562	761	11 152
Hong Kong (China)	1 251	89	87	1 427
Singapore	610	41	144	795
India	177	2	379	558
China	408	18	49	475
Malaysia	43	5	1	49
Saudi Arabia	35	-	4	39
Thailand	36	-	2	38
Indonesia	27	-	4	31
Turkey	24	-	-	24
Latin America and the Caribbean				
Brazil	191	54	9	254
Bermuda	140	30	-	170
Mexico	101	6	12	119
Bahamas	54	-	-	54
Argentina	27	5	1	33
Cuba	3	-	16	19
Chile	15	-	2	17
Panama	14	1	-	15
Uruguay	3	-	-	3
South-East Europe and the CIS				
Russian Federation	126	-	37	163
Ukraine	8	-	3	11
Bulgaria	7	2	-	9

Source: UNCTAD, based on information from the USPTO patent database.

Note: When patents are assigned to an individual, they are counted as "domestic firms". The classification of assignees is according to the *Who Owns Whom* database and other sources. The *Who Owns Whom* database gives information on the "Ultimate Parent". Foreign affiliates are those firms whose ultimate parent is in a different country.

were in computers and electronic products industries in 2002 (figure IV.9, see also annex table A.IV.2). In India, over three-quarters of affiliates' R&D expenditures ($61 million) were in non-manufacturing industries in 2002, compared to only about 20% in 1999, probably reflecting a focus on software development in that country. On the other hand, chemicals and transportation equipment combined accounted for over half of all R&D by foreign affiliates of United States TNCs located in both Brazil (figure IV.9) and Mexico (Moris 2005a). These patterns are different from that of the aggregate for all host countries, in which transportation equipment was the top industry, followed by computers and electronic products, with chemicals and pharmaceuticals in third place (figure IV.9, annex table A.IV.2).

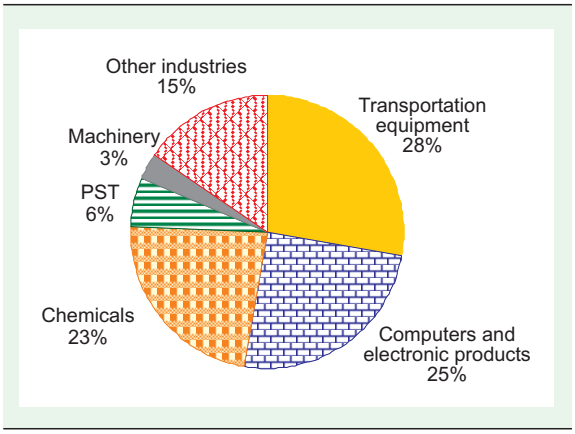
Overseas R&D by German TNCs shows similar patterns. In the electronics and semiconductor industries, both industries with a high percentage of production abroad, Asia was an above-average location in 2000, while R&D by the German chemical and pharmaceutical TNCs was heavily skewed in favour of North American locations. The remaining industries appeared to focus on Europe (Ambos 2005, p. 400).

The industry composition of recent greenfield R&D projects in 2002-2004, for which information was available, also shows a high share of information technologies (IT) and software in new projects in developing countries (39%), which may indicate a gradual shift of R&D towards services and in particular IT. [36] IT is gaining importance within R&D because, in more and more TNCs, the share of software

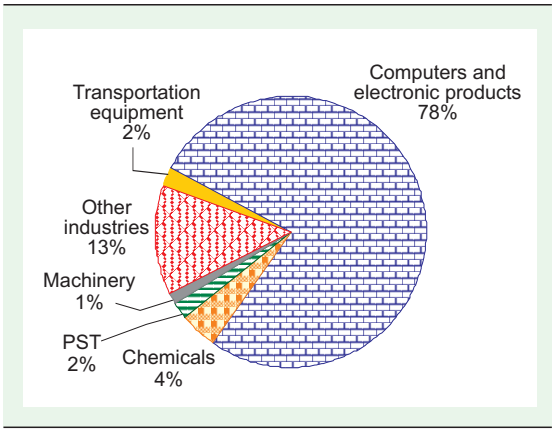
Figure IV.9. Industry composition of R&D by majority-owned foreign affiliates of United States TNCs, 2002

(Per cent)

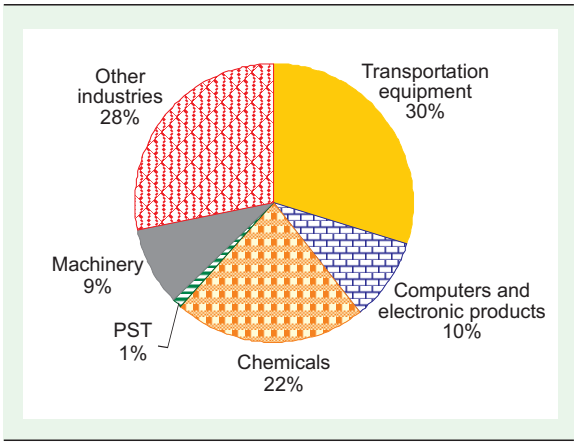
a. All host countries



b. Asia (excluding Japan)



c. Brazil



Source: UNCTAD, adapted from Moris 2005a, based on data from United States Bureau of Economic Analysis, *Survey of United States Direct Investment Abroad,* www.bea.gov/bea.

Notes: Data are preliminary estimates. PST refers to professional, scientific, and technical services. Data for transportation equipment for affiliates in Asia (excluding Japan) and Brazil are for 2001. Data for PST services for affiliates in Japan and Asia (excluding Japan) are for 2001.

development is taking up an increasing part of the R&D budget.[37]

2. Types of R&D

R&D carried out by TNCs in developing countries can be categorized in various ways (box IV.4). One relates to the types of R&D undertaken by TNCs' affiliates in host countries, reflecting the different technological functions assigned to foreign affiliates. The foreign affiliates may undertake:

- Adaptive R&D;
- Innovative R&D linked to production for local or regional markets;
- Global innovative R&D for new products or processes, or for basic research; and
- Technology-monitoring R&D.

There can be many varieties of *adaptive R&D*, ranging from basic production support to the upgrading of imported technologies. Not all TNC production abroad gives rise to formal R&D (as a distinct operation separate from routine engineering or initial plant design). Much depends on the size and growth of the local facility, the differences between local conditions and those for which the technology was designed, and the availability of local technical skills. The extent to which adaptive R&D evolves into *innovative* R&D depends even more on the

availability of suitable technical skills along with supplier R&D capabilities (where this feeds into the R&D done by an affiliate) and institutional support (for testing or other specialized work). *Innovative R&D for local or regional markets* can evolve into *global innovative R&D* when the host economy is able to meet even more stringent skill and institutional needs. However, this evolution is not the only way for TNCs to launch R&D in developing countries. Some developing countries are attracting "pure" TNC R&D, not related to production (either for the domestic market or export-oriented). *Technology monitoring units* are another example of R&D. The main roles of technology monitoring units are to keep abreast of technological developments in foreign markets and to learn from leading innovators and consumers there (Roberts 2001).

It is difficult to quantify R&D according to the types identified above (the data are too limited). However, one study, undertaken in 1999 on 209 R&D performing firms from the Triad (Roberts 2001), found that the establishment of worldwide centres of excellence for a particular technology or discipline was the primary function of overseas R&D; it varied between a high of 47% for Western European TNCs and a low of 25% for Japanese firms (Roberts 2001, p. 30). Adaptation for local markets was a close second in Japan and the United States, and a distant second in Western Europe. Regional technical support activities and basic and/or applied research in other countries held third and fourth places respectively. In developing countries, while most R&D has traditionally been of an adaptive nature, recent trends suggest that more sophisticated activities are also expanding. A 2004 survey found that 22% of the respondents

Box IV.4. Taxonomy of R&D by foreign affiliates

Overseas R&D by TNCs is a multifaceted activity. For instance, it can be analysed in terms of the nature of the activity undertaken or in terms of the motives for undertaking R&D abroad. According to these two criteria, the typologies overlap considerably and distinctions are not always easy to draw; moreover, over time the distinctions can become increasingly blurred as R&D units evolve.

The following provides illustrations of the two typologies based on the nature of the R&D activity and on TNC motivations. Despite the fact that these two taxonomies are drawn from a large body of literature that has focused almost entirely on R&D by foreign affiliates in developed countries, they can also be applied, in most cases, to the developing countries that are emerging in the global R&D landscape.

Based on the nature of technological activity in foreign affiliates: This typology divides foreign affiliates doing R&D into four broad types (sometimes with sub-categories) on the basis of the kind of R&D undertaken (Pearce 1989, Nobel and Birkinshaw 1998, von Zedtwitz 2005).

- *Local adapters:* These are "market-seeking" R&D units for absorbing and adapting technologies, essentially to support product and process engineering departments in making existing technologies work more efficiently in new environments. They are also variously called "support units" and "technology transfer units".
- *Locally integrated laboratories*: Also called "indigenous technology units" and "international independent laboratories", these are more advanced than local adapters and are capable of independent innovation aimed primarily at local (and perhaps regional) markets. The units remain linked to local production and are usually a natural evolution from adaptive R&D.
- *International technology creater:* This is the most advanced type of innovative activity by foreign affiliates and places them on an equal level with core innovating centres in the home countries and in other developed countries. Also known as "internationally interdependent laboratories" or "global technology units", these facilities can do both research and development, and their output is typically aimed at global exploitation by the parent company. They may evolve out of locally integrated laboratories, and so retain tight links with production in the host economy, or they may be set up independently of local production to tap local innovation clusters and skills.
- *Technology scanning or monitoring unit:* This is normally a "business intelligence" function undertaken by an "asset-seeking" R&D unit

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Box IV.4. Taxonomy of R&D by foreign affiliates (concluded)

under the headings above, but in the absence of a separate R&D facility, scanning can also be done by another department of the TNC.

***Based on TNC motivation*:** This typology groups affiliate R&D activities by the technological objectives of the parent company (Le Bas and Sierra 2002). Four types emerge:

- *Technology-seeking FDI in R&D:* The TNC seeks to offset areas of weakness in the home-country innovation system by setting up R&D facilities or acquiring local innovators in countries with complementary strengths. A number of R&D-related M&As in the United States in biotechnology, electronics and pharmaceuticals are of this type. Developing-country firms with technological ambitions also undertake such R&D investments or acquisitions.
- *Home-base (or asset-) exploiting FDI in R&D*: This essentially corresponds to the adaptive category in the typology above, where the main functions of the R&D are to absorb and adapt technologies transferred by the parent company so that the TNC can effectively exploit its technology assets.
- *Home-base (or asset-) augmenting FDI in R&D*: This is where TNCs undertake R&D in technologies in which they are strong at home and where the host country also has strengths. This has been called "strategic asset-seeking R&D" by TNCs. It aims not only to access foreign technological assets but also to capture the externalities created by host-country technology clusters (Dunning and Narula 1995). The distinction between this and technology-seeking FDI is not very strong, especially in the case of developed countries, as it hinges on an evaluation of the relative strengths of home- and host-country innovation systems.

There are other ways to classify foreign R&D. It is possible to categorize it, for example, by the organizational strategy of TNCs and by their R&D management practices. However, for the purposes of analysing the impact on developing countries, the relevance of these taxonomies is more limited.

Source: UNCTAD, based on the literature cited.

[a] Based on Archibugi and Iammarino 2002, Le Bas and Sierra 2002, Edler et al. 2002, Gassmann and von Zedtwitz 1999, Gerybadze and Reger 1999, Kuemmerle 1997, Medcof 1997, Nobel and Birkinshaw 1998, Pearce 1989 and 1999, Reddy 2000, Ronstadt 1977, Voelker and Stead 1999, von Zedtwitz 2005, and von Zedtwitz and Gassmann 2002.

were already conducting some applied research in overseas developing markets (EIU 2004a).

The following analysis looks at the salient features of TNC-controlled R&D in developing countries, beginning with the region where the magnitude of the phenomenon is the highest. It stresses that Asia has taken the lead among developing countries not only in terms of the number of projects and jobs created but also in terms of the types of R&D undertaken, including innovative R&D for local and global markets. Indeed, some R&D activities in some Asian developing countries in particular are now taking on a more sophisticated role within the global R&D networks of TNCs. The analysis of developing Asia is followed by those of Latin America and the Caribbean, and Africa respectively. An analysis of the economies in transition of South-East Europe and the CIS, and of the former economies in transition of the new EU members[38] is added at the end of the section because R&D-related FDI in those countries has grown fast, and in some respects the features of these economies with regard to skills and wage advantages are similar to the ones offered by various developing countries at comparable income levels.

a. Asia and Oceania: dynamic trends

The rise of developing Asia and Oceania has been the most dramatic development in the global landscape of R&D. Some economies in the region have been able to capture a broad range of R&D functions from TNCs, including innovative R&D and basic research. For example, electronics firms in Taiwan Province of China are attracting the outsourcing of complete product design (Engardio and Einhorn 2005). While most developing host economies do not offer the advanced design and production capabilities of Taiwan Province of China, the kind of work they

conduct can also be quite sophisticated. Contract manufacturers like Flextronics (Singapore), for instance, set up R&D bases in some countries such as India and China in 2004 in order to provide state-of-the-art product development services (Engardio and Einhorn 2005). Meanwhile, pharmaceutical companies are seeking to cut the cost of bringing new drugs to the market by collaborating with biotech firms in India. Thus the dividing line between the kind of R&D that is suited for expansion in developing countries and that which is best kept at home – or in developed as opposed to developing countries – has become blurred.

China and India have been the main beneficiaries of this trend. Of the 885 R&D-oriented greenfield FDI projects announced in the region in 2002-2004, three-fourths (723) were concentrated in these two large economies. In China, some 700 foreign-affiliate R&D centres had been established by the end of 2004 (box IV.5). In India, more than 100 TNCs have established R&D facilities.[39] Microsoft launched its sixth global research centre in Bangalore in early 2005 after opening one in Beijing in 1998. Other such Microsoft R&D centres outside the United States are located in the United Kingdom and the Republic of Korea. In the case of Motorola (box IV.6), 6 of its 19 main R&D centres are located in developing countries: five in Asia (China, India, the Republic of Korea, Malaysia and Singapore) and one in Brazil. The number of large pharmaceutical TNCs that have a research presence in India in particular is growing fast. Astra-Zeneca inaugurated a large facility for research on tuberculosis in 2003 and subsequently expanded it to include pharmaceutical development. Pfizer started clinical research in India in 1995 and added a biometrics unit in 1998 along with a formulation development group in 2004. In addition, as of June 2005, Eli Lilly,[40] Sanofi-Aventis, Novartis and GlaxoSmithKline had clinical research units and Novartis and GlaxoSmithKline had biometrics centres in India (Mukherjee 2005).

FDI in R&D in Asia and Oceania flows not only to very large countries like China and India but also to other, smaller, economies in the region. Data on greenfield projects in 2002-2004 show that at least 16 other Asian economies received R&D-oriented FDI during the period of observation. Within this group, East and South-East Asian economies, especially Hong Kong (China), Malaysia, the Philippines, the Republic of Korea, Singapore, Taiwan Province of China, and Thailand, frequently appear on the radar screen of TNCs.

Those economies that traditionally have had a considerable presence of foreign affiliates in local innovation (e.g. Singapore) also have a large share of business R&D (figure IV.6). Over the past decade more than 100 TNCs, including Rolls Royce, Motorola, Philips, GE, Delphi, Eli Lilly, Hewlett-Packard, Matsushita, Sony, 3M and DaimlerChrysler, have located R&D laboratories in Singapore (Toh 2005, pp. 11-12). More recently, pharmaceutical TNCs such as Aventis, Merck, GlaxoSmithKline and Wyeth have set up R&D facilities there (annex table A.IV.3). In Thailand, the size of FDI in R&D was small over the period of 1995-1999 averaging $4.1 million per annum, although it accounted for an important part of business R&D (Intarkumnerd and Sittivijan 2005, pp. 4-5). By the period 2000-2004 both business R&D and R&D by foreign affiliates had increased substantially (the latter to $34 million per year).[41] The industry focus of R&D-related FDI in Thailand, too, shifted between the two periods, from metals and non-metal-working industry to machinery, transportation equipment (led by Japanese TNCs such as Toyota; box IV.7) and electrical appliances (especially hard disk drives).

The share of foreign affiliates in R&D expenditure in the Republic of Korea is still low (figure IV.6). It is only recently that TNCs have started investing in R&D in that country, in part as a response to more active government policies that welcome and encourage such FDI (chapter VII). As of December 2004 a total of 140 foreign-affiliate research institutes had been opened, 61 of which were established after 2000 (Republic of Korea, Ministry of Commerce, Industry and Energy 2005). Most foreign research institutes are now using their facilities to develop new products and processes, and in some recent cases they are performing innovative R&D activities for global innovation and production (box IV.8).

Some of the development work conducted in Asia is world-class, such as chip design in the semiconductor industry. This industry was one of the earliest to globalize production in developing countries, and has been among the first to move advanced design to selected developing economies including the Republic of Korea, Taiwan Province of China, and, more recently, to China, India, Singapore and Malaysia (annex to chapter V). Asia is not only undertaking

Box IV.5. The boom in R&D-related FDI inflows in China

R&D-related FDI inflows in China have surged in recent years. The accumulated R&D investment of TNCs in China had reached approximately $4 billion by June 2004 (estimated by the Ministry of Commerce), while the number of foreign-affiliate R&D centres, registered according to the eligibility criteria in place since the year 2000, reached 700 by the end of 2004. Although the first TNC R&D centre dates back to 1993, most of the known projects are recent (established after China's accession to the WTO in December 2001).

Most foreign-affiliate R&D centres are wholly-owned by their parent companies, although some of them are joint ventures (such as the one established by Lenovo and Intel in 2003). The majority of these centres still focus on adaptive innovations for the Chinese market. However, some do innovative R&D that is closely integrated with TNCs' global innovation networks, and thereby target global markets.

R&D-related FDI inflows have been concentrated in technology-intensive industries such as ICT, automotive and chemicals (according to the data of the Beijing Municipal Bureau of Statistics). The ICT industry, in particular, has witnessed a boom in R&D investment by TNCs (box table IV.5.1). Motorola (see also box IV.6), one of the largest foreign investors in China, had set up 15 local and global R&D centres in China by the end of 2004, with several others under construction. In addition to Motorola, major R&D investments have been made by Microsoft, Nokia, GE (box table IV.5.1) as well as IBM, Siemens, Nortel, Dupont, General Motors, Honda, Hitachi and Toshiba, to mention only a few (Sigurdson 2005a, p. 2).

Foreign-affiliate R&D centres in China are concentrated in large cities with strong technological bases and skilled human resources, particularly in Beijing and Shanghai (box figure IV.5.1). At the end of 2004, 189 centres were located in Beijing alone, with almost 60% of them in the ICT industry. Many of them followed on the footsteps of IBM, which established its wholly-owned R&D centre there in 1995. Within the capital, the Haidian District (where Zhongguancun Science Park is located) is home

Box table IV.5.1. Selected foreign affiliate R&D centres in the electronics and ICT industries of China, as of 2004

Company	Number of R&D centres in China	Location	Features
General Electric	1	Shanghai	• China Technology Centre, opened in Shanghai in 2003, is the third global R&D centre of the company after those in the United States and India. • Invested $640 million and centralized its previous by existing R&D units in China. • 500 R&D engineers (planned to increase to 1,200 in 2005).
Microsoft	5	Beijing Shanghai	• Invested $130 million. • Microsoft Research Asia (MRA), established in 1998, is the company's basic research facility in the Asia and Oceania region and the fifth largest research centre in the world. • MRA employs over 170 researchers.
Motorola	15	Beijing Shanghai Tianjin Suzhou Nanjing Chengdu	• The first TNC R&D centre in China (set up in 1990). • Total of 1,300 R&D engineers. • Invested $300 million in R&D in China until 2001. • Motorola China Research Institute (MCRDI) was established in 1999. • Will invest $500 million in a new R&D centre in Beijing.
Nokia	5	Beijing Shanghai Hangzhou	• Nokia China R&D Centre, established in 1998, employs 300 R&D engineers. • Hangzhou R&D Centre, established in 1998, employs 180 R&D engineers (will increase to 400).

Source: UNCTAD, based on company press information.

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more chip-related R&D; the levels of complexity of this R&D are also on the rise. A few firms from the Republic of Korea and Taiwan Province of China, and to a lesser extent from China and India, now develop cutting-edge technology.

In sum, the range of R&D activities undertaken by or for TNCs in Asia, mainly in information technology and pharmaceuticals, is surprisingly wide:

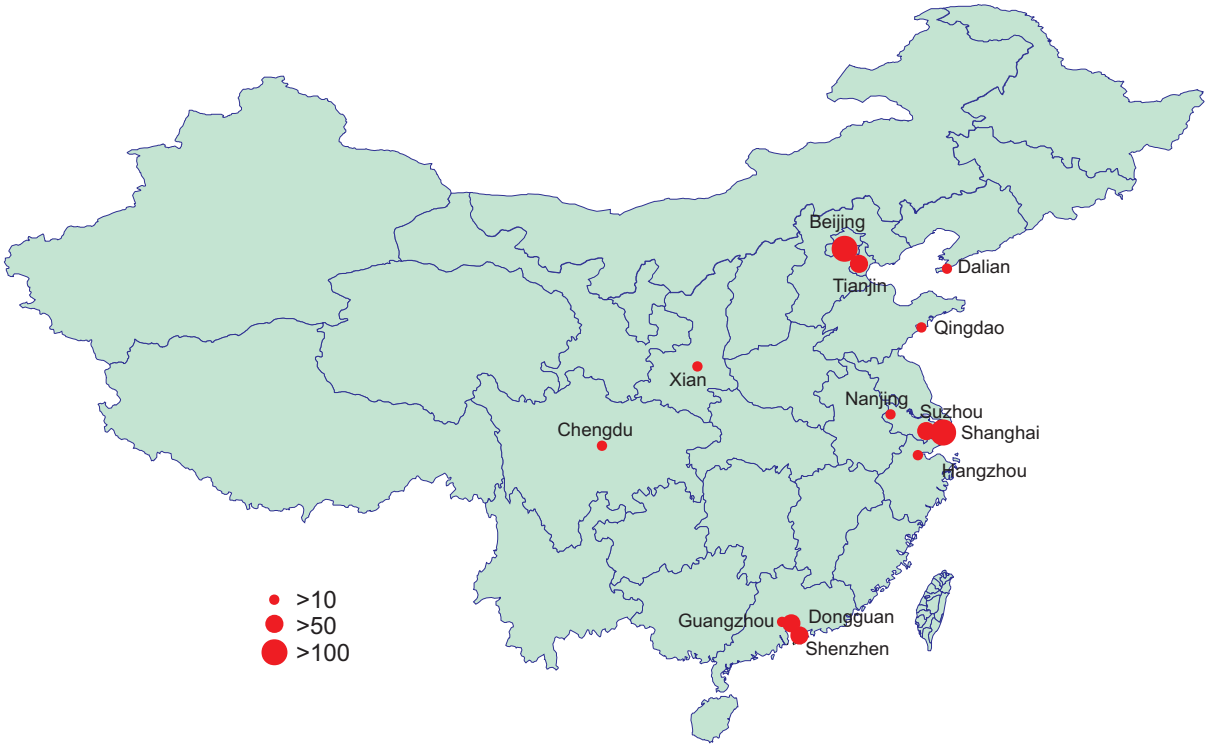
> "Today, the likes of Dell, Motorola, and Philips are buying complete designs of some digital devices from Asian developers, tweaking them to their own specifications, and slapping on their own brand names. It's not just cell phones. Asian contract manufacturers and independent design houses have become forces in nearly every tech device, from laptops and high-definition TVs to MP3 music players and digital cameras… While the electronics sector is furthest down this road, the search for offshore help with innovation is spreading to nearly every corner of the economy... [Boeing] is working with India's HCL Technologies to co-develop software for everything from the navigation systems and landing gear to the cockpit controls for its upcoming 7E7 Dreamliner jet. Pharmaceutical giants such as GlaxoSmithKline and Eli Lilly are

Box IV.5. The boom in R&D-related FDI inflows in China (concluded)

to 40 universities and 130 research institutes and is the capital city's R&D hub.

In Shanghai, over 140 TNC R&D centres have been established, of which 91 are in the Pudong New District. In addition, the Guangdong and Jiangsu provinces had accounted for 28% and 19% of the accumulated FDI inflows of China until 2003 (estimated by the Ministry of Commerce) and are home to more than 100 foreign-affiliate R&D centres. Some other regional economic centres in other coastal provinces such as Hangzhou in Zhejing province, Qingdao in Shandong province and Dalian in Liaoning province have also attracted important foreign-affiliate R&D centres (box figure IV.5.1). Finally, TNCs have also set up some R&D centres in a limited number of inland cities such as Xi'an and Chengdu.

Box figure IV.5.1. Location of foreign-affiliate R&D centres in China, 2004
(Numbers)



Source: UNCTAD.

Box IV.6. Motorola's R&D network

Telecommunications equipment manufacturer Motorola (United States) is the world's 19th largest R&D spending firm (table IV.1). As of end 2004 it operated major R&D centres (those with over 100 R&D staff) in 19 countries worldwide: two in North America, six in the EU-15, one in Poland, three in other developed countries, six in developing countries, including Brazil, China, India, the Republic of Korea, Malaysia and Singapore, as well as one in the Russian Federation (box figure IV.6.1).

The first overseas R&D centres were opened in 1950 in Canada and the United Kingdom, followed by various other European locations in 1960. Motorola began conducting R&D in developing countries fairly early, with operations in Singapore and Malaysia already in place in 1970. Most R&D centres concentrate on product development rather than on research. The latter is conducted in only five countries, three of them developed (the United States, the United Kingdom and Israel) and two of them developing: India and China.

The R&D activities of Motorola in China illustrate well the interaction between a TNC with a global network of R&D centres and a wide-ranging host-country R&D structure including business and government R&D units (Sigurdson 2005a). Motorola has also entered into a number of collaborative research agreements with local universities, which also explains the broad presence of its R&D centres in the country. Motorola originally focused on manufacturing in China. In the early 2000s, the company increased its R&D activities in China to be closer to the local market and to be more cost-efficient.

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teaming up with Asian biotech research companies in a bid to cut the average $500 million cost of bringing a new drug to market" (Engardio and Einhorn 2005, pp. 52-53).

b. Latin America and the Caribbean: limited R&D but with potential

TNCs have so far located only limited R&D in Latin America and the Caribbean. FDI there is rarely in R&D-intensive activities, and when it is, it mainly remains confined to adaptation of technology or products for local markets, called "tropicalization"[42] in the Latin American context (Cimoli 2001). Foreign affiliates play a relatively large role in business enterprise R&D in Brazil and Mexico, moderate in Argentina and low in Chile (figure IV.6).

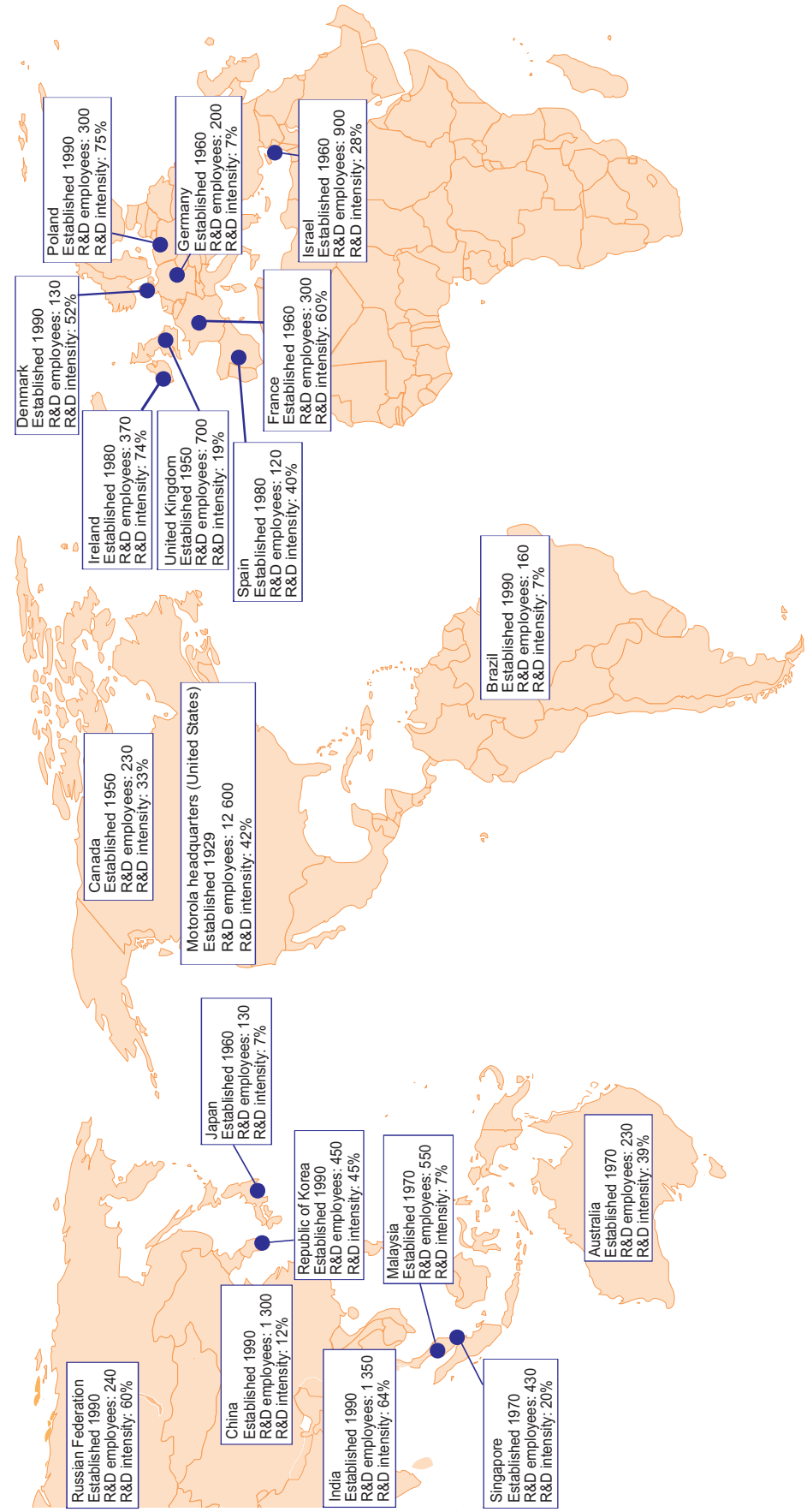
Employment data for the majority-owned foreign affiliates of United States TNCs show that, while the share of Latin America and the Caribbean in 1999 was about 20% of the worldwide total employment in such foreign affiliates, the share of the region in R&D employment of foreign affiliates was only 7% (table IV.7).[43] Most of this is in two countries: Brazil and Mexico (table IV.6).

In Brazil, adaptive R&D dominates, although some change has been noted in the strategies of some TNCs since the late 1990s. They include Brazilian affiliates in their strategy of globalization of R&D, upgrading their technological activities and giving them new R&D responsibilities (Costa 2005). This has occurred mainly in the auto parts and automotive industries (box IV.9) as well as in the electronics industry. In these industries some TNCs have reversed previous downsizing of local R&D activities,[44] following their loss of market share either locally or regionally (Costa 2005, Queiroz et al. 2003, Furtado et al. 2003, Consoni and Quadros 2003, Galina 2003). The pharmaceuticals industry displays a different pattern: few pharmaceutical TNCs do R&D in Brazil, despite the availability of local capabilities and public laboratories (Costa 2005, Furtado et al. 2003).

In Mexico foreign affiliates are active mainly in assembly work, relying on their parent companies for most R&D activities. Innovation in export-oriented TNCs appears to be confined to organizational and marketing activities rather than product and process technology (Abdel Musik 2004). A study of Mexico's Baja California electronics and automotive manufacturing cluster concluded that more than a quarter of the plants surveyed were engaged in R&D, one-fifth did

Box IV.6. Motorola's R&D network (concluded)

Box figure IV.6.1. Motorola's R&D network, 2004



Source: UNCTAD, based on information and data provided by Motorola.

product design, more than one-tenth had developed a patent and more than one-third had ISO 9002 Certification (Gerber and Carillo 2002). An example of R&D for global markets is found in the automotive industry of Mexico. For instance, Delphi Automotive (United States) has a technical centre in Ciudad Juárez employing 3,000 people, half of whom are engineers designing auto parts for global use. Examples of R&D for the regional market can be found in the country's banking industry (BBVA of Spain).

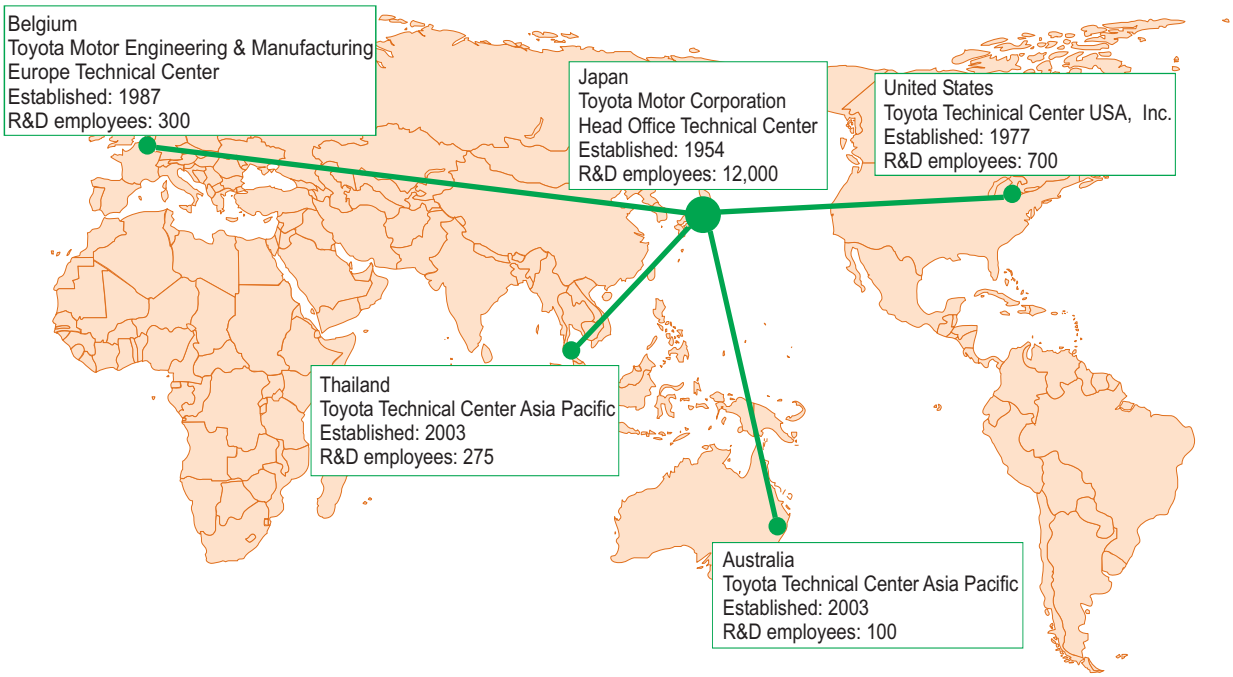
Box IV.7. Thailand in Toyota's global R&D network

Toyota Motor Corporation founded its fourth overseas R&D centre – and the first one in a developing country (box figure IV.7.1) – in Thailand in August 2003.[a] The "Toyota Technical Center Asia Pacific (Thailand)" was officially opened in May 2005. Toyota has invested 1.1 billion baht ($27 million) into this centre so far. During the two-year preparation for opening, almost all locally recruited engineers and scientists were sent to Japan for a training period of 6 to 12 months.

When it first opened, the "Toyota Technical Center Asia Pacific (Thailand)" employed 275 persons (including 32 Japanese), of which 250 were engineers and technicians (2% of Toyota's global R&D staff). The centre has both a regional mandate for Asia (excluding China) and a global one to carry out R&D for the parent corporation. It is in charge of projects in basic research, technology development, research on market conditions and design, along with testing and evaluation.

Thailand was chosen as a location for Toyota's Asian R&D centre for various reasons. The existence of a manufacturing and sales affiliate there was an important consideration, although there is no equity or administrative link between the two units. Other reasons include good local infrastructure, political stability, favourable geographical location, a skilled labour force and favourable government policies (including incentives). In the area of policies, outstanding issues include the eventual exemption from customs duties of materials (such as motor vehicles) imported for testing, and the provision of full licences for test-driving.

Box figure IV.7.1. Toyota's global R&D network, 2005



Source: UNCTAD, based on company interview conducted on 4 May 2005.

[a] The other overseas R&D centres are in the United States, Europe and Australia (see box figure IV.7.1).

Box IV.8. Innovative R&D by foreign affiliates in the Republic of Korea: Microsoft, Siemens and Philips

The Republic of Korea has recently attracted innovative R&D centres from a variety of major TNCs.

In March 2005, United States software maker *Microsoft* opened its Mobile Innovation Lab at the headquarters of its Korean affiliate, Microsoft Korea, in Seoul to develop technology for wireless devices. The company is committed to creating software programmes for next-generation mobile devices. Microsoft has plans to invest up to $30 million in this R&D centre over the next three years, and employ 30 researchers.

Siemens, the German electronics and information communications corporation, announced in June 2004 that it would invest $119 million in the Republic of Korea over five years. The investment was intended to establish a forward base of information communications and network equipment in the country and develop products for the world market. Siemens had invested $45 million by early June 2004 and had bought a 38.7% share of Dasan Networks (Republic of Korea), making it that company's largest shareholder. Siemens is developing Dasan Networks into an R&D centre and distributes communications and network equipment to world markets, including those in Europe, the United States and Asia.

In 1999, *Royal Philips Electronics* of the Netherlands acquired a 50% share of LG Electronics' LCD (liquid crystal display) division for $1.6 billion. The new joint-venture company plans to invest a total of $10 billion and build the LG-Philips Plant on a 408-acre site in Paju, Gyeonggi Province by 2006. Along with the production lines, LG-Philips plans to set up an R&D centre to develop technology for next generation TVs.

Source: UNCTAD, based on information provided by the Ministry of Information and Communication of the Republic of Korea, *Investment Opportunities in Broadband IT Korea, 2004*, www.mic.go.kr, www.investkorea.org.

Box IV.9. General Motors in Brazil: from tropicalization to global innovative R&D

General Motors has an important R&D centre at its Sao Caetano plant in southern Brazil. Established in the 1960s as a small unit to adapt ("tropicalize") GM autos and parts to Brazilian conditions, it became a large laboratory by the end of the 1980s, focusing on a variety of projects directed at the host-country market. By the late 1990s, GM Brazil had accumulated technical expertise in designing local versions of GM models such as the Opel Corsa sedan, the Corsa pickup and the Astra sedan. The continuous building up of the product development engineering team and local infrastructure permitted GM Brazil to go further through engagement in the Blue Macaw project, origin of its Celta model.

After 1996 the Brazilian automotive regime became increasingly open to parts imports while still protecting the assemblers with fiscal advantages and import tariffs. GM responded to those policies by streamlining its manufacturing process, whereby suppliers co-located their production of sub-assemblies for GM cars at the assembly plant in Rio Grande do Sul, thereby reducing GM's inventory holdings.

Concomitantly, GM also changed the mandate of its Brazilian R&D centre from local to international: GM Brazil was assigned responsibility for designing a new vehicle for global sales (the Meriva minivan). Instead of following the usual strategy of car makers, which consisted of designing a partial derivative of an already existing model, GM Brazil was given responsibility for a more complex project called "global derivative" consisting of designing a new vehicle for global rather than local application (Consoni 2004).

These additions to GM Brazil's portfolio of activities have meant expanded product and process development for both local and global applications. About 1,000 technical and hourly employees are now engaged in product development in Brazil, and about 500 in process engineering R&D work. The value of this activity is not large when considering GM's global R&D activities, although it has increased the responsibility and autonomy of the Brazilian R&D team significantly. Today, GM in Brazil competes with other GM affiliates in the United States, Europe and Asia for the right to design and build new vehicles and to carry out other core activities for the global company.

Source: UNCTAD, based on company interview.

c. Africa: generally marginal in R&D by TNCs

In Africa the R&D component of FDI is overall very small. With a few exceptions such as Kenya, Morocco and especially South Africa, R&D by TNCs is virtually absent. This is partly because of weak domestic R&D capabilities (chapter III) and, in many cases, the lack of institutional mechanisms that provide incentives for investors to devote resources to R&D (Oyelaran-Oyeyinka 2004a). This does not necessarily mean that innovation per se is absent from Africa but rather that such innovation is undertaken outside R&D laboratories.

In the South African auto industry – in which all assemblers are wholly or partly owned by their respective parent companies from Japan, Europe or the United States – firms spend 2.5% of their total sales on R&D (UNCTAD 2003b, p. 16). This is generally carried out in collaboration with the South African Bureau of Standards (SABS) and the engineering faculties of some of the leading universities.[45] Collaboration between SABS and the automotive foreign affiliates has led to the establishment of the EuroType Test Centre, a state-of-the-art laboratory that has made South Africa one of the world leaders in testing engines and catalytic converters. In the South African aerospace industry, BAE Systems of the United Kingdom contracted Aerosud South Africa as an exclusive supplier of leading-edge wing components for the Airbus A320 jetliners.[46] In health care, Innovex, a South African affiliate of Quintiles (United States), offers contractual services for clinical testing, health economics, marketing and sales.

North Africa provides some recent examples of FDI in R&D. Morocco has attracted R&D centres, especially in software and electronics: SQLI (France) set up an R&D platform in the country in 2003, Eolane Electronics Manufacturing Services (France) opened an R&D centre in the country in 2004 next to its manufacturing and distribution unit, and STMicroelectronics has had a chip design Centre in Casablanca since 2000 (box IV.10). In the automotive industry, Pininfarina/Matra (Italy) opened a 60-person R&D centre in Morocco in 2004, together with a test circuit. Other North African countries are less targeted by R&D,

Box IV.10. STMicroelectronics' design and software centre in Rabat

In 2000 STMicroelectronics (registered in the Netherlands and headquartered in Switzerland) located parts of its design activities in Morocco.[a] The Rabat Design Centre is part of a global network of 16 advanced R&D centres and 39 design centres in the Czech Republic, France, Germany, India, Italy, Morocco, Tunisia, the United Kingdom and the United States. Within this network, the primary mission of the Rabat Design Centre is to develop advanced system-on-chip products for digital TVs, DVD players and flat-screen displays, along with digital still and video cameras. The Rabat Centre currently employs 170 people, scheduled to grow to 700 by 2009.

In addition, the firm has established a training centre, the first of its kind in the country, to train teachers and students from engineering schools and to provide them with the necessary syllabus to enable them to make a valuable contribution to the innovation needs of the semiconductor industry. In 2001 it launched its first cooperative activity with the Mohammed V-Agdal University in Rabat, which included scholarships, exchange programme and sponsorship of microelectronics courses. It also established a design centre at the Mohammadia School of Engineers, within the Mohammed V-Agdal University.

STMicroelectronics chose Morocco as the location for the design centre for several reasons. These included a favourable educational and communications infrastructure, the availability of a rich pool of engineering talent, the proximity of Europe and competitive costs. Rabat was chosen specifically for its schools and universities that train engineers specialized in the computer/IT domain.

Source: STMicroelectronics.

[a] The presence of the seventh largest semiconductor producer in the world (49,000 employees worldwide) in Morocco dates back to 1952. Operations in Morocco were expanded in 1979 to carry out subsystem development, and again in 1997 to create a state-of-the-art "back-end" assembly and test plant.

though in Algeria the Jordanian pharmaceutical firm Hikma opened an R&D centre at its local factory in 2003, while Novell (United States) entered into a strategic alliance with Net-Skills, a local software firm (Marseille Innovation and ANIMA 2005).

The rest of the R&D-related FDI in Africa mirrors the resource-based orientation of the continent, focusing on petroleum exploration and exploitation and agriculture. In the petroleum industry, a number of TNCs[47] conducted some R&D in Algeria, Egypt, Morocco, the Libyan Arab Jamahiriya and Tunisia in 2004.[48] In agriculture, the United States-based Agro-Management Group developed pyrethrum flowers in Uganda, for the international market.[49] Kenya is also home to selected agricultural R&D projects carried out by and for TNCs and their affiliates (box IV.11).

d. A comparison with economies in transition

In the former transition economies that are now new EU member countries, foreign affiliates have become important R&D players since the mid-1990s (figure IV.6, box IV.12). This has happened partly through the early acquisition of flagship firms carrying out R&D such as Škoda Auto in the Czech Republic in 1991 and Tungsram in Hungary in 1990. In those instances the new owners decided to transform the local R&D laboratories of the acquired affiliates into specialized corporate R&D centres. The majority of the R&D privatized laboratories acquired by foreign investors in the acceding new EU member countries managed to adapt to the new environment of increased competition from imported technologies. An UNCTAD survey of privatization through FDI carried out in 1999[50] found that in the two years following the privatization deals, R&D expenditure increased by 13.6% in the sample firms (Kalotay and Hunya 2000, p. 53).[51]

In the new EU member countries, R&D by foreign affiliates has also expanded through greenfield projects. Of the 108 R&D projects initiated in the new EU, South-East Europe and the CIS taken together in 2002-2004, 66 were registered in the new EU member countries, with the Czech Republic, Hungary and Poland taking the lead. Information on key R&D affiliates in

Box IV.11. R&D by TNCs in agriculture: Kenya

Kenya is not a major player in global R&D. In agriculture, which generates a large share of its export earnings, R&D expenditures represented only slightly more than 1% of the total for developing countries in 2000.[a] Moreover, the private sector accounted for only 3% of total agricultural R&D expenditure in Kenya that year.[b]

There are however several agricultural/horticultural or related firms, including TNCs, conducting some form of R&D in Kenya. The known cases of R&D by TNCs in Kenya have followed different strategies. Some have decided to conduct in-house R&D. Examples include De Ruiter's, Regina Seeds, Fourteen Flowers (the Netherlands), Del Monte (United States) and Kordes & Söhne (Germany). Other TNCs such as East African Breweries (United Kingdom), Monsanto (United States) and Syngenta (Switzerland), have opted for collaborative arrangements with local and foreign partners. The Kenyan Agricultural Research Institute (KARI) carries out research on barley on behalf of the East Africa Breweries, and works for Syngenta to develop insect-resistant maize for Africa. Monsanto's involvement in Kenyan R&D is more indirect, as its project initiated originally in direct collaboration with KARI and the International Service for the Acquisition of Agri-tech Applications has been transferred to its United States non-profit partner, Donald Danforth Plant Science Center.[c]

Source: UNCTAD.

[a] CGIAR, ASTI Database (www.asti.cgiar.org/expenditures.cfm), and Beintema, N. and Phillip G. Pardey (2001). "Slow magic: agricultural R&D a century after Mendel", ASTI Initiative, IFPPI, mimeo.

[b] The share of private firms in Kenyan agricultural R&D may be higher, because the original sample was based on information available on only three firms.

[c] The non-profit Donald Danforth Plant Science Center is a partnership organization of the Monsanto Company and various United States-based academic research institutions.

these three countries in 2004 suggests a dominance of EU-15 investors, although the United States, Japan and some developing economies (India, the Republic of Korea) are also among the home countries. Most of these affiliates are linked to manufacturing sites, and hence are mainly in the automotive and electronics industries (including spare parts producers and telecom equipment manufacturers). Various affiliates on the list have "innovative" R&D mandates for regional or global markets.

In South-East Europe as well, foreign affiliates have gained a prominent role in R&D. In Romania, for example, Automobile Dacia (affiliate of French Renault) and Petrom (now affiliate of Austrian OMV) were the two largest R&D spenders in the country in 2003. In Bulgaria, Bulgarian Telecom (65% owned by Viva Ventures, United States) was the second largest R&D spender in the same year.

In the CIS, and the Russian Federation in particular, the entry of TNCs in R&D has remained at a low level and in most cases is limited to alliances or other contractual arrangements. Boeing (United States), Pratt & Whitney (United States), Airbus (France/Germany/Spain/United Kingdom) and Dassault (France) have been actively cooperating with the R&D institutes and laboratories of the Russian aerospace industry and the Russian Academy of Sciences since the early 1990s (Ivanova 2004, p. 151). For example, one of the leading Russian R&D centres, the Zhukovski Central Aerohydrodynamics Institute, has contributed to R&D on the Hermes air space system and the DASA Hypersonic vehicle, on commercial transporter A3XX and on Boeing's 757 and 777 aircraft (Ivanova 2004, p. 152). Outside the Russian Federation, Antonov, the leading Ukrainian aviation firm, signed in 2002 contracts to modernize Chinese aircraft in cooperation with Shanxi Aircraft Industry based on earlier Antonov designs (Yegorov 2004, p. 159).

R&D on a basis other than contractual ties is less frequent in the CIS. As a whole, there were only 30 greenfield R&D projects reported in the LOCOmonitor database for the CIS in 2002-2004, of which the Russian Federation alone accounted for 27. Compared to the science and technology base in the Russian Federation that number is small but could grow rapidly in the near future. One of the largest of the foreign-affiliate R&D

Box IV.12. R&D by foreign affiliates in the Czech Republic

As in most new EU member countries, the Czech R&D system underwent a major transformation during the transition from centrally planned to market economy. In this process, foreign affiliates have become important players in the national R&D system, accounting for nearly 47% of business expenditure on R&D in 2003 (figure IV.6) and for 30% of business R&D employment in 2002.

R&D activity of foreign affiliates is typically related to the presence of manufacturing plants in the country, although this trend might be changing as a consequence of several greenfield projects that have been attracted into strategic services recently. In pure R&D activities (stand-alone R&D laboratories, ISIC 73) foreign affiliates play a limited role, accounting only for 6.3% of employment in 2002. The R&D services industry received only 0.1% of total FDI inflow until the end of 2002 (more than 80% of which came from Germany).

In manufacturing, most of the business R&D is concentrated in medium-technology industries such as automobiles, which accounted for 68.2% of manufacturing-related R&D in 2002. Automotive production has a long tradition in the Czech Republic with Škoda Auto, taken over by Volkswagen in the early 1990s, as the main showcase. Foreign affiliates in the automotive industry are committed to the long-term upgrading of their overseas R&D, as their patenting record and their cooperation agreements with universities and R&D laboratories indicate. This contrasts with the case of electronics, another significant FDI recipient in the Czech Republic. Activities in that industry are driven primarily by local cost advantages, with limited investment in overseas R&D. In fact, in this industry the R&D intensity of foreign affiliates is substantially lower than that of domestic firms.

Source: UNCTAD, based on Srholec 2005.

centres of the Russian Federation was opened by Intel in 2000 (box IV.3). In another case, the European Aeronautic Defence and Space Company, the parent firm of Airbus (EADS, headquartered in the Netherlands), opened a 30-employee engineering centre in Moscow in 2003 together with the Russian Federation's Kaskol Group, an aerospace and defence conglomerate that controls the MiG producer in Nizhny Novgorod.[52]

E. Developing-country TNCs are also expanding R&D abroad

Another new trend whereby developing countries are connecting to global knowledge networks is the emergence and fast growth of foreign R&D activities by TNCs from developing economies. As the phenomenon is very recent, the top R&D spenders of developing countries are still relatively small (section A and table IV.1). However, some – almost all from Asia – have moved up in ranking on the list of the largest R&D-spending firms since the late 1990s. Moreover, the expansion of their R&D appeared to be on a relatively large scale in 2002-2004 (table IV.9).

Some developing-country TNCs such as the IT company, Ingenuity Solutions (Malaysia), have targeted the knowledge base of developed countries such as the United States, when investing in R&D abroad. Similarly, Bionova of Mexico acquired DNA Plant Technology of the United States in 1996 and, as a more recent example, the Singaporean firm Cordlife, acquired Cytomatrix (United States) in 2004.

There are also examples of South-South FDI in R&D. A number of firms from Malaysia, the Republic of Korea, Singapore, and Thailand have set up R&D activities in India related specifically to software development (Reddy 2000, pp. 97-103). In 2003 Samsung Electronics (Republic of Korea) announced plans to open R&D centres in China, India and the Russian Federation; LG (Republic of Korea) has expanded its R&D activities into India; and Bogasari International (Indonesia, food processing) chose Singapore, in part due to the country's favourable R&D incentive schemes for foreign investors.

The following section examines the cases of Chinese, Indian and Korean TNCs, which are among the most active developing-country firms establishing R&D activities abroad.

A recent study of large *Chinese TNCs* found that they operated 77 R&D units at the end of 2004, including a surprisingly high 37 units abroad (von Zedtwitz 2005). Of these foreign R&D units, 26 are located in developed countries, predominantly in the United States (11) and Europe (11), mostly serving as listening posts or in product design roles.[53] The remaining 11 units, located in developing countries, are typically small in size (e.g. just a handful of people in a small technology outpost in Pakistan and the Islamic Republic of Iran).[54] Two Chinese TNCs, Huawei[55] and Haier,[56] are illustrative of the trend of R&D units being located mainly in developed countries. Other Chinese companies from the electronics industry, such as ZTE and UTStarcom, have also established R&D centres in India aimed essentially at offshore software development.

Indian TNCs are also globalizing their R&D, focusing mainly on serving their customers in specific regional markets. The leading software firms have all invested abroad, mostly in developed countries. For example, Infosys, Wipro, Birlasoft (part of Aditya Birla Group) and HCL Technologies have operations in the United States. They are also moving into selected developing-country locations where they have major customers, especially China, South-East Europe and the CIS.[57] Some Indian software R&D affiliates are located in other developing regions (e.g. Tata has invested in Uruguay) as well as in new EU member countries (Hungary). Indian firms in other industries such as pharmaceuticals and chemicals are also investing in R&D abroad (box IV.13).[58]

TNCs from the Republic of Korea started establishing R&D affiliates abroad only in the 1990s. In 2005, a survey carried out by the Korea Industrial Technology Association identified 60 foreign R&D centres owned by Korean firms. The United States was the main target of such investment (17 R&D centres) followed by China (15), Japan (7), the Russian Federation (5) and Germany (5). The majority of R&D centres in China (12 of the 15) have been operating since 2000. Some of the Korean firms investing abroad in R&D also figure prominently on the list of the

700 largest R&D-spending companies of the world (table IV.1): these include Samsung Electronic (33rd in world ranking and the largest R&D spender in the developing world),[59] Hyundai Motor (95th) and LG Electronics (110th).

F. Prospects

In sum, TNCs are dominant players in global R&D, and their R&D is being increasingly internationalized, including in developing countries. The trend towards the greater involvement of developing countries in the R&D activities of TNCs is likely to accelerate, although, to date, the majority of developing countries remain excluded from this phenomenon. Whether R&D activities will spread to a growing number of developing countries remains an open question, and will largely depend on the policies pursued by these countries (chapter VII).

In the UNCTAD survey of the world's largest R&D-spending TNCs, as many as 69% of the responding firms stated that their share of foreign R&D is set to increase; only 2% indicated the opposite, while the remaining 29% expected the level of internationalization to remain unchanged (figure IV.10).[60] The momentum appears to be particularly strong among companies in Japan and the Republic of Korea, which have so far been less aggressive in terms of R&D internationalization. Nine out of ten Japanese companies in the sample and about 80% of the Korean firms planned to increase their foreign R&D, while 61% of European firms indicated similar intentions. This finding is corroborated by information provided by the Government of Japan: 95% of Japanese affiliates abroad plan either to expand their R&D activities (17%) or to maintain them (78%) at the same level as before, regardless of their location (Japan, METI 2004).

Box IV.13. Alexandria Carbon Black: Indian FDI in R&D in Egypt

The Aditya Birla Group is one of India's top TNCs. It has 72,000 employees worldwide and manufacturing units in Australia, Canada, China, Egypt, Indonesia, Malaysia, the Philippines and Thailand. In 1994 the company established the Alexandria Carbon Black (ACB) factory in Egypt. Owing in part to continuous product and process innovation, the ACB plant has grown to become one of the world's largest single carbon black plants.[a] It employs 300 persons in Egypt, 25 of whom work in its R&D centre.

The ACB plant has a sophisticated R&D centre with the latest analytical equipment. The centre has, among other things, developed a key grade of carbon black for providing critical properties to the final product. Other innovations include manufacturing process improvements to improve quality and increase efficiency, utilization of information technology to computerize processes, innovations in the area of packaging and environment management, as well as adopting total quality management and total productive maintenance.

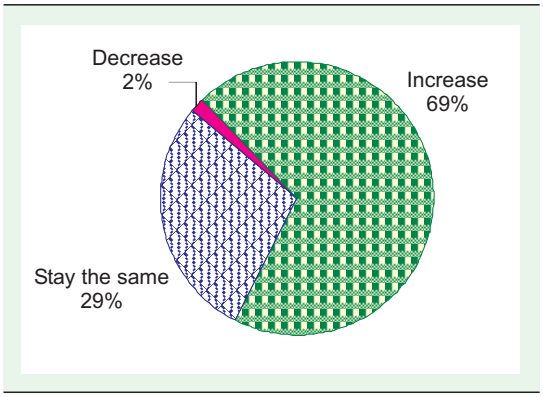
The R&D centre provides various forms of technical support to domestic enterprises. Local companies can use the centre's analytical equipment, and it also provides training to employees of local companies. The training includes best practices in quality management, how to use sophisticated analytical equipment, statistical quality control tools and total productive maintenance. In order to upgrade the skills of the employees of its suppliers, the company also offers technical and managerial support. Some development work (e.g. related to improvements in raw material and packaging) has also been done in partnership with suppliers. Six major partnerships with suppliers have been forged in the areas of packaging, raw materials and manufacturing of sophisticated equipment. As a founding member of the Regional Geographical Committee of the Petro-Chemical Area, ACB also helps the adoption of best practices by local companies.

The R&D centre is closely collaborating with the parent company's Fundamental Research Institute in India. The Aditya Birla Group provides significant support to ACB in a number of areas, and members of ACB's technical team frequently travel to other carbon black units of the group to exchange experiences and learn from the others.

Source: UNCTAD, based on information provided by Alexandria Carbon Black in March 2005.

[a] Carbon black is a key raw material input mainly for the manufacture of tyres and other rubber products.

Figure IV.10. Prospects of TNCs locating R&D abroad, 2005-2009
(Per cent of responses)



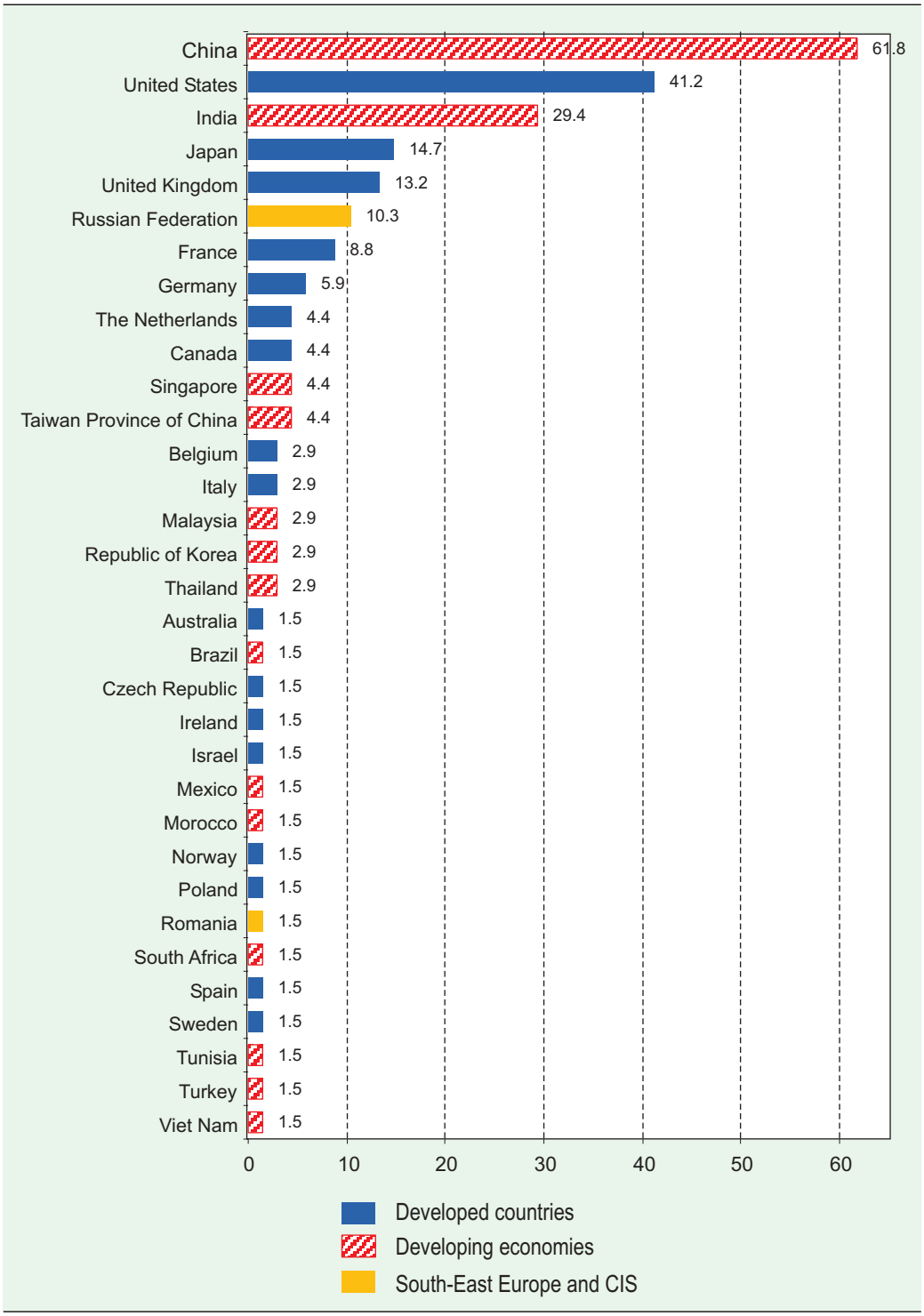
Source: UNCTAD survey.

A further shift towards some specific developing, South-East European and CIS markets is also expected (figure IV.11). In the above-mentioned UNCTAD survey, for instance, China was the R&D destination mentioned most often, followed by the United States. In third place was India, another significant newcomer location for R&D. The Russian Federation was also among the top 10 target locations for R&D expansion. Other developing economies that were mentioned as candidates for further R&D by at least 2% of the companies were the Republic of Korea, Singapore, Taiwan Province of China and Thailand. However, only a few respondents indicated possible plans for expanding R&D in Latin America and Africa. Another survey (EIU 2004a) reached similar conclusions, with the top 10 destinations for R&D expansion including three developing economies: China for R&D expansion (in first position), India (3rd) and Brazil (6th); and three others in the following ranks: Hong Kong, China (13th), Mexico and Singapore (both14th) (EIU 2004a).

* * *

This chapter has examined the dominant role of TNCs in global R&D along with the rise of some developing countries as locations chosen for TNC-led R&D. It has also analysed the shifts in the industry composition and the mandates of the R&D carried out abroad, especially in developing countries. In particular it has shown that R&D in some developing countries increasingly involves "innovative" activities. It has found that TNCs from developing countries are also investing in R&D abroad. The next chapter examines the drivers and determinants of the internationalization of R&D by TNCs, with the aim of determining the implications for development (chapter VI) and deriving some policy lessons (chapter VII).

Figure IV.11. Most attractive prospective R&D locations in the UNCTAD survey, 2005-2009
(Per cent of responses)



Source: UNCTAD survey.

Notes

1 Some pharmaceutical firms with no identified foreign affiliates pursue their internationalization through strategic alliances with TNCs. For example, Cell Genesys is in a technology alliance with Novartis (Switzerland). The latter is also a 5% shareholder of the former. Human Genome Sciences (United States) has strategic alliances with GlaxoSmithKline (United States), Takeda (Japan), Schering-Plough (United States), Sanofi-Synthelabo (France), Merck (Germany) and the Pharmaceutical Division of the Kirin Brewery (China). In another case, ICOS (United States) is a 50% owner of the Lilly ICOS joint venture formed with Eli Lilly (United States) for the global distribution of the drug Cialis.

2 In 2003, the R&D expenditure of the 700 largest spenders rose further, by more than 5%, to $327 billion.

3 In Sweden, the top 20 TNCs accounted for up to three-quarters of the total R&D expenditure in the late 1980s (Håkanson and Nobel 1993a). In Germany, only 49 firms accounted for two-thirds of the privately funded R&D spending in the late 1990s (Ambos 2005, p. 398).

4 Zander, 1994, Håkanson and Nobel 1993a, Pearce 1989, Dalton and Serapio 1995, von Zedtwitz and Gassmann 2002.

5 R&D expenditure data are for R&D activity regardless of the source of funding. The R&D data from the United States Bureau of Economic Analysis (BEA) defines R&D to include basic and applied research in science and engineering as well as the design and development of prototypes and processes. R&D expenses include wages and salaries, taxes, materials and supplies, depreciation, amortization, and allocated overhead and indirect costs, but exclude capital expenditures. R&D expenses also exclude routine product testing and quality control conducted during commercial production, geological and geophysical exploration, market research and surveys, and legal work pertaining to patents. BEA data used here exclude banks and other depository institutions. However, data on the distribution of overseas R&D in terms of basic, applied and development expenditures, along with their cost components (e.g. labour, equipment, taxes) are not available. Expenditure data are in current dollars (Moris 2005a). For further information and survey methodology, see http://www.bea.gov/bea/di/usdscrpt.htm.

6 R&D employment data from the United States BEA *Survey of U.S. Direct Investment Abroad* are available only every 5 years from benchmark surveys. The latest available data are for 1999.

7 In local currency, total R&D spending increased from 36 billion Swedish kronor to 47 billion Swedish kronor.

8 Granstrand 1999, Sachwald 2004a, Archibugi and Michie 1995, Archibugi and Iammarino 2002, Molero 1998.

9 Roberts (2001) and Edler et al. (2002) surveyed 209 Triad firms each; von Zedtwitz and Gassmann (2002) conducted a total of 290 interviews (over the period 1994-1998).

10 In order to eliminate the distortions caused by under- and over-representation, this has been calculated as a weighted average of responses using the regional distribution of the 316 questionnaires for weighting. Due to the over-representation of Western Europe in the responses, the unweighted average would have been 34%.

11 Not all firms answered both questions.

12 Previous studies (Roberts 2001, Edler et al. 2002, von Zedtwitz and Gassmann 2002), while finding that the Western European firms were the most internationalized, also noted that their lead over the United States TNCs was small. In the Edler et al. 2002 survey (p. 158), the European firms were estimated to spend one-third of their R&D budget abroad in 2001, followed closely by the North American firms (32%), and only very distantly by the Japanese firms (11%). In Roberts' (2001) survey, Western European firms were estimated to spend 35% of their R&D budget abroad, followed by the North American firms (33%) and the Japanese firms (10%). The discrepancy with the UNCTAD survey is due to the fact that the survey by Roberts treated intra-European and intra-North American R&D flows as domestic.

13 These are estimates based on data from 30 economies, which accounted for 99% of global business R&D in 2002. For more details, see the note in annex table A.IV.1.

14 The presence of India in this group may be surprising. The low share of foreign affiliates in total R&D spending in India may be due to various factors. One is that the latest statistics available are only for 1999 (i.e. the period before the take-off of many large projects). A second reason may relate to the definition of R&D: India specializes in software development, an industry that is not always categorized as R&D in statistics. Finally, many of the projects started in India have been of a non-equity nature, and hence are not reflected in FDI.

15 The share of foreign affiliates in the R&D of the transition economies of South-East Europe may be equally high, while that of the CIS is probably low.

16 Historical data were missing for two economies: Italy and Thailand.

17 Such as in the case of the merger between Sweden's Astra and the United Kingdom's Zeneca, the acquisition of the United Kingdom's Celltech by Belgian UCB, or the takeover of Škoda Auto by Volkswagen in the Czech Republic and Tungsram by GE in Hungary.

18 These foreign affiliates are engaged in commercial, physical and educational research (Standard Industrial Classification (SIC) code: 8731), commercial economics and biological research (SIC code 8732), non-commercial research (SIC code: 8733) and testing labs (SIC code: 8734) as their main activity.

19 Maastricht Economic Research Institute on Innovation and Technology, *Cooperative Agreements and Technology Indicators* (MERIT CATI) database.

20 Source: MERIT-CATI database.

21 Prior studies concluded similarly that R&D activities were not equally distributed around the world and tended to reside mostly in developed countries (Gassmann and von Zedtwitz 1999, Meyer-Krahmer and Reger 1999, Schmaul 1995, Archibugi and Iammarino 2002).

22 Information in this discussion related to the United States is based in part on a background paper prepared

by Francisco Moris (Moris 2005b) for *WIR05*.

23 Surveys are conducted at five-year intervals. The results for 2004 are not yet available.

24 R&D bases are key nodes of R&D, typically regrouping various affiliates. Hence the number of bases is lower than the number of foreign affiliates.

25 LOCOmonitor collects, validates and crosschecks real-time information on new (greenfield) and expansion FDI projects worldwide. Both announced and realized FDI projects are included. Each project identified is cross-referenced against multiple sources and the company website. Full global data collection started in 2002. Each FDI project is classified into one "key" business function (out of a list of 17, including R&D) and, if applicable, into additional business functions (following the same categorization). As a result, the number of projects whose "key" business function is R&D is smaller (1,489 over the period 2002-2004, annex table A.I.3) than the number of projects for which R&D is "any" business function (1,773 over the same period of time). The data presented in this Report refer to the second, broader definition of R&D. The usual caveat on completeness and accuracy of information applies.

26 The source of these categories is von Zedtwitz 2005.

27 The Edler et al. 2002 survey concluded in a similar way (pp. 159-160) that North America and Western Europe were the most attractive target regions for foreign R&D, while Japan's attractiveness for R&D carried out by TNCs from abroad was well below the country's science and technology potential. Among the developing regions and South-East Europe and the CIS, the "Asian Tigers" were mentioned by 23% of the firms surveyed. "Eastern Europe" (12%) and Latin America (10%) were far less important, while Africa was hardly mentioned.

28 Bulgaria was mentioned by only one respondent. The rest of South-East Europe and the CIS did not appear on the investment map for R&D.

29 Respondents indicated only regions and not individual countries.

30 For the analysis of the innovatory activities in developing countries, USPTO data are preferred over national patent data and those of other developed countries, since they are regarded as providing a more comparable and representative measure of such activities (chapter III).

31 USPTO glossary, www.uspto.gov/main/glossary/index.html.

32 The total number of USPTO patents granted increased by 70% in the same period.

33 For some patents, the USPTO database does not identify any assignees. In such cases, it is assumed that the inventor(s), to whom the patent is granted, remains the legal owner.

34 In 2003, 17 patents (13% of that year's total) were granted to the Brazilian affiliate of Johnson & Johnson (United States), and five patents to the Brazilian affiliate of Dana Corporation (United States) for instance.

35 In India, the Council for Scientific and Industrial Research was the most important institute with 324 patents.

36 Data from the LOCOmonitor database.

37 For Ericsson (Sweden), over the past 40 years, R&D in telecommunications equipment production has shifted from hardware to software. Today, the company is spending 85% of its R&D budget on software development (Goldstein and Hira 2004).

38 In the new United Nations classification, the eight former Central and Eastern European economies in transition that joined the EU in 2004 are shown as part of the developed-country group, under the category of the EU-25 (box I.2). For analytical purposes, especially when drawing conclusions from the lessons of transition, their experience is shown here together with that of South-East Europe and the CIS.

39 These TNCs include Caterpillar, Cisco Systems, DaimlerChrysler, Du Pont, General Electric, General Motors, Hewlett Packard, IBM, Intel, Lucent, Microsoft, Motorola, Oracle, Philips, SAP and Texas Instruments. For instance, GE's John F Welch Technology Center in India, with an investment of $80 million and 1,600 employees, is the company's first and largest R&D centre outside the United States (LOCOmonitor database).

40 The R&D centre of Eli Lilly is its largest research facility in Asia and the third largest in the world.

41 Estimates by the Board of Investment of Thailand. An alternative source of information, the R&D/Innovation Survey of the National Science and Technology Development Agency for the year 2003, has estimated the R&D expenditure of majority-owned foreign affiliates to be about $40 million (about 28% of the total R&D expenditure of the private sector) in that year (Intarkumnerd and Sittivijan 2005, pp. 5-6), indicating that the Board of Investment may have underestimated the R&D expenditure of local firms.

42 The term "tropicalization" has been used in particular to denote the adaptation of automotive products to the local conditions and climate of Brazil (Kuntz 1999).

43 By comparison, the corresponding figures for foreign affiliates in developing Asia were 13% and 8%.

44 This happened with the car makers Ford and Volkswagen, and the telecom equipment supplier Alcatel (Costa 2005, p. 6).

45 At the University of Stellenbosch, for example, important work has been done on emission control and engine testing in collaboration with regulatory bodies in the EU.

46 Source: *BusinessDay* (www.bday.co.za/bday).

47 They include Burlington Resources, Amerald Hess Corporation, ConocoPhilips, Anardarko and Occidental Petroleum Corporation (Oxy) from the United States, and Woodside from Australia, BG Group from the United Kingdom, Repsol from Spain and Edison from Italy.

48 Their R&D focuses on integrated sedimentology, geochemistry, seismic interpretation, petrophysics, reservoir engineering and petroleum geology research (narg.web.mcc.ac.uk/home.html).

49 www.roncoconsulting.com/post-conflict/uganda.html.

50 The survey, conducted from January to June 1999, reviewed the pre- and post-privatization performance of 23 major companies selected from seven countries, of which five became new EU members in 2004 (the Czech Republic, Hungary, Latvia, Poland and Slovenia) and two are candidates for accession (Croatia and

Romania). The combined asset value of these large enterprises at the moment of their privatization exceeded $5 billion — 8% of the inward FDI stock of the seven countries in 1999 (Kalotay and Hunya 2000, p. 52).

51 Unpublished data of the Hungarian Central Statistical Office on the performance of foreign affiliates in 1992-1998 (reported in Kalotay 2000, p. 165) confirm the rising trend of R&D: over the period of observation, the R&D expenditure of foreign affiliates in Hungary increased from $6.3 million to $96.5 million, raising the R&D intensity of these firms (measured as a percentage of total sales) from almost nil to 0.4% of total sales.

52 EADS holds a 51% share in the venture. Komarov, Alexey, "EADS East Airbus-trained Russian engineers, data exchange network in place", *Aviation Week & Space Technology*, 159,6, 11 August 2003, p. 54.

53 Japan, with only two Chinese R&D units, seems to be somewhat underrepresented in the sample, probably due to the small sample size. However even in the complete database of 776 international R&D units, Japan has only 55 or approximately 7% of total foreign R&D laboratories (von Zedtwitz 2005).

54 One exception is Huawei's software laboratory in Bangalore (550 engineers in 2003, expected to grow to more than 2,000 by 2005). The value of that investment was almost $100 million, or about 7% of Huawei's overall R&D activities.

55 In addition to Bangalore, Huawei has also invested in Stockholm (Sweden), Moscow (Russian Federation) and Dallas (United States).

56 Haier operates ten small-scale research units abroad, which focus on technology monitoring and other R&D activities.

57 Jointly with GE for instance, TCS has established an R&D centre in Hangzhou, the capital city of Zhejiang province in China. Other top Indian IT services players such as Infosys, Satyam and Wipro have also invested in China.

58 For example, in 2003 the pharmaceutical firm Ranbaxy (India) set up a new plant in Abu Dhabi that will also conduct R&D.

59 The operations of Samsung Electronics are particularly R&D-intensive, accounting for 8% of revenues in 2003. Ten of its 16 R&D centres are located abroad (China, India, Israel, Japan, the Russian Federation, the United Kingdom, and the United States). Its global R&D network develops new technologies in digital media, telecommunications, digital appliances and semiconductors. The company also carries out joint R&D projects through strategic alliances with Sony, IBM, Hewlett-Packard and Microsoft.

60 Similar observations were made in another recent survey (EIU 2004a), in which more than half of the respondents were planning to increase their overseas R&D investment. And a DIHK survey conducted in 2005 found that nearly 20% of German companies planned to move R&D jobs abroad in the next three years (DIHK 2005b).