Can be posted on the Web.
E 21/11/03.

Global investment in R&D today

A statistical survey of R&D expenditure and research personnel worldwide

GUNNAR WESTHOLM, BERTRAND TCHATCHOUA AND PETER TINDEMANS

United Nations Educational, Scientific and Cultural Organization

Global investment in R&D today

A statistical survey of R&D expenditure and research personnel worldwide

GUNNAR WESTHOLM, BERTRAND TCHATCHOUA AND PETER TINDEMANS

Prepared by
UNESCO's Sector of Natural Sciences
in cooperation with
the UNESCO Institute for Statistics

(ref: SC/EO/SPI/UIS/03)

Foreword

The present study should be viewed as a snapshot of the investment different regions of the world are currently making in scientific research and experimental development (R&D) in terms of human and financial resources.

The same methodological approach is used on that adopted for the previous report published by the UNESCO Institute for Statistics (UIS) in 2001 on *The State of Science and Technology in the world 1996–1997*[1], which covered indicators of both input and output. This approach includes the 'now-casting' model developed by Messers Nghia Bui Quang and Shiu-Kee Chu, former members of the UIS, and Bertrand Tchatchoua.

Global investment in R&D today updates the previous study to analyse emerging trends in expenditure and research personnel between 1997 and 2000[2]. To avoid a distorted picture, a handful of leading countries are singled out in each regional analysis.

The present study draws on a number of international data sources. Data on research and development (R&D) are taken from UNESCO[3], the Organisation for Economic Cooperation and Development (OECD[4]) and the Latin American Network for S&T Indicators (*Red Iberoamericana de Indicadores de Ciencia y Tecnología*, RICYT[5]). Economic background series come from the World Bank. Recognizing the need for greater linkages between international data sources in science and technology, representatives of these and other international bodies, as well as selected national experts, participated in a meeting convened by UNESCO's Institute for Statistics and UNESCO's Division of Science Analysis and Policies in Paris in March 2003 on the theme of Towards a New UNESCO Strategy in Science and Technology Statistics.

A number of recent regional or national R&D reports have also provided key information. Special thanks go to Drs Jacques Gaillard and Nabiel A.M. Saleh for providing data for the African and Arab states respectively.

GUNNAR WESTHOLM, BERTRAND TCHATCHOUA AND PETER TINDEMANS

1 Available at: http://www.uis.unesco.org/
2 Data for some countries may be for 1999 rather than 2000. Similarly, data for 1997 in the earlier report may be for 1996 for some countries.
3 Databases of the UNESCO Institute for Statistics (Montreal).
4 OECD (2003) *Main Science and Technology Indicators 2003/1*
5 RICYT (2001) *El Estado de la Ciencia – Principales Indicadores de Ciencia y Tecnología Iberoamericanos/Interamericanos*

Contents

Photo: Dominique Roger © UNESCO

A future based on knowledge

Moving towards a knowledge-based global community

A future based on knowledge

Many of the challenges countries and regions of the world are facing in such areas as sustainable development, economic growth, health care, education and agricultural production are increasingly subsumed to a common denominator: developing knowledge-based societies and economies. While the process towards knowledge-based societies is driven to a large extent by the industrialized countries, it is now widely recognized that 'catching up' in areas like those mentioned above depends crucially on acquiring, developing, managing and properly applying appropriate knowledge. Major factors underlying this trend are global institutions and arrangements (such as the World Trade Organization, the various development banks and the UN system) and the spread of information and communication technologies (ICTs).

There are, of course, huge discrepancies between countries and (sub-)regions in their approaches to building a knowledge-based society. The form this process takes, and the urgency with which it is pursued, differs greatly for instance, between the rapidly growing economies of China, Brazil or the newly industrialized Asian economies (the 'dragons') on the one hand and what one is seeing in many resource-based economies, on the other. And while the need to follow this path does not go unnoticed in many of the poorer countries, the difficulties in jumping on the bandwagon are enormous and the process itself is sometimes perceived as only widening the gap between them and the richer countries of the world.

Knowledge underpinning development is, of course, not equal to scientific knowledge. But no country will be able to achieve and durably maintain prosperity and a high quality of life without using the results of science and without ensuring a well-educated population. This was the underlying notion of the World Conference on Science organized in 1999 by UNESCO and ICSU. The *Declaration on Science and the Use of Scientific Knowledge* and the *Science Agenda: Framework for Action* adopted at this Conference set out principles and guidelines for a beneficial relationship between science and society, and for the development and use of science to the advantage of the whole world community. Science, it was stressed, must be seen to encompass the natural, engineering and social sciences as well as the humanities. Equitable and sustainable development can only be achieved by making all countries share in developing and using science. Within countries, women (but also other disadvantaged groups) need to participate widely to make this endeavour inclusive rather than exclusive. Equitably balancing and sharing the benefits of science between the interests of international and local industry, global finance and local capital, national and local communities requires rethinking access to information, protecting value and reward systems. International partnerships shored up by new financial schemes are vital to strengthen capacity-building. The relationship between science and society and between science and government has to be characterized by greater openness, transparency and mutual involvement. In this relationship, public debate of ethical issues has its place as an important interface between science and society.

Measuring progress towards a knowledge-based future

Can we see the world's countries and regions moving towards knowledge societies? Can we measure and monitor this process? And, conversely, can we interpret whatever information we collect on how countries invest in science and use it, in terms of progress towards a knowledge-based society?

There is a long tradition of collecting data on the efforts of public and private actors in the various countries of the world in science and technology (S&T), and of turning these data into indicators of a country's performance in these fields. We are now used to trying to measure not only input – basically investment – in S&T, but also output: what do we get in return for our investments? But as we come to understand better how companies and societies benefit from S&T, there is a growing need for increasingly sophisticated, complex and broader indicators of the actual processes that lead to prosperity and quality of life. For example, innovation is the mechanism through which S&T 'deliver' but it involves much more than simply these two activities. Much of the theoretical effort, as well as the testing of the resulting methods, occurs in industrialized countries of course, where S&T efforts are considerable and differentiated, and the tradition of collecting statistical data is well-established. A very useful tool for both policy-making and public debate on a country's performance are, for instance, compound indicators that combine data on the creation and diffusion of knowledge, S&T performance and the 'productivity' of the economy, the education system and the information infrastructure. These are now being used in the European Union to give a bird's eye view of investment and performance in the 'knowledge-based' economy.

The UNESCO Institute for Statistics, which surveys worldwide trends and compares the investment and performance of countries and regions across the globe, can build on these efforts. At the same time, it is clear that the problems of collecting truly comparative data and making sense of them are huge for the many countries that play only a minor role in S&T. Yet the stakes are high. No single country has succeeded in achieving and durably sustaining high levels of prosperity and comfort without investing in S&T and exploiting them. The effort therefore must be sustained. Even the most straightforward of input data can point to very real trends in development. More often than not, alas, these trends are only too indicative of the snail's pace at which we are progressing towards the overall goal of equitable global development.

The present study

The present study concentrates on the most straightforward of input data, namely financial investment in research and development (R&D) and the number of researchers in the different regions of the world. It updates to 2000 the data of the previous report from the UNESCO Institute for Statistics (2001) on *The State of Science and Technology in the World 1996–1997*. These data reveal interesting trends for development projects and policy-making. For example, a recent survey[6] among Western European and North American companies shows that 14% of them have R&D activities in China, a figure that is expected to rise to 20% in three years' time. Here we have a new phenomenon of 'brain drain' not of people but of jobs. This trend will be reflected in the share of foreign finance in total Chinese R&D expenditure.

[6] Deloitte survey of 600 firms in Western Europe and North America, published in The Netherlands, October 2003.

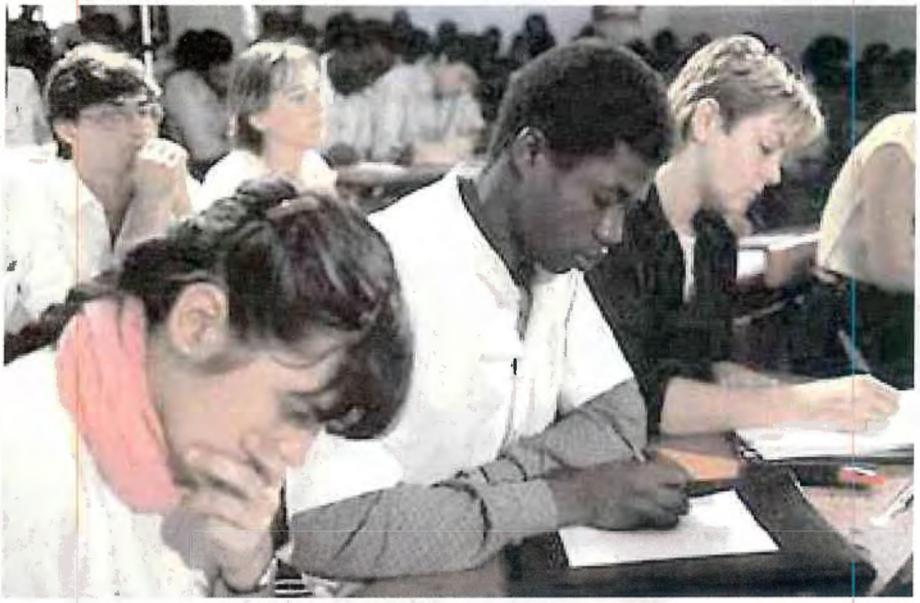


Photo: Dominique Roger © UNESCO

Measuring progress towards a knowledge-based future

TABLE

Key indications of world GDP, population and R&D expenditure and personnel in 2000

Regions/Countries	GDP		Population		R&D Expenditure (GERD)				R&D Researchers (FTE)			GERD per Researcher (Thousand $PPP)
	GDP $PPP (Billion)	% World GDP	Population (Million)	% World Population	GERD $PPP (Billion)	% World GERD	% GDP	GERD per capita ($PPP)[1]	Researchers (thousand)	Researchers % World	Researchers per million inhabitants	
WORLD	43394.3	100.0	6024.9	100.0	745.7	100.0	1.7	124	5276.6	100.0	876	141.3
Developed Countries	25338.2	58.4	1245.4	20.7	597.0	80.1	2.4	479	3778.9	71.6	3034	158.0
Developing Countries	18056.1	41.6	4779.5	79.3	148.7	19.9	0.8	31	1497.7	28.4	313	99.3
Americas	13080.7	30.2	817.9	13.6	302.3	40.5	2.3	370	1333.0	25.3	1630	226.8
North America	10413.1	24.0	308.7	5.1	281.2	37.7	2.7	911	1205.4	22.7	3904	233.3
Latin America & Caribbean	2667.6	6.1	509.1	8.4	21.3	2.9	0.8	42	127.6	2.4	251	166.7
Europe	12130.8	28.0	725.3	12.0	202.9	27.2	1.7	280	1782.7	33.8	2458	113.8
European Union	9274.0	21.4	375.5	6.2	174.7	23.4	1.9	465	969.1	18.4	2581	180.3
Central & Eastern Europe	1008.1	2.3	126.9	2.1	9.1	1.2	0.9	71	162.5	3.1	1280	55.7
Community of Independent States (in Europe)	1492.7	3.4	210.5	3.5	12.8	1.7	0.9	61	634.7	12.0	3016	20.2
Other Europe	356.0	0.8	12.5	0.2	6.3	0.8	1.8	507	16.5	0.3	1324	383.0
Africa	1580.9	3.5	779.0	12.9	4.2	0.6	0.3	5	60.9	1.2	78	69.2
Sub-Saharan Countries (excl. Arab-States)	978.7	2.3	601.7	10.0	3.2	0.4	0.3	5	30.9	0.6	51	102.4
Arab States in Africa	602.2	1.4	177.3	2.9	1.1	0.1	0.2	6	30.0	0.6	169	35.0
Asia	16034.5	37.0	3673.0	61.0	227.8	30.5	1.4	62	2028.5	38.5	552	112.3
Japan	3394.4	7.8	126.6	2.1	98.2	13.2	2.9	779	658.9	12.5	5206	149.6
China	5019.4	11.6	1253.6	20.8	50.3	6.7	1.0	40	695.1	13.2	554	72.3
Newly Industrialized Economies (in Asia)	2865.7	6.6	444.3	7.4	48.2	6.5	1.7	109	262.4	5.0	591	183.8
India	2242.0	5.2	997.5	16.6	12.2	1.6	0.5	12	142.8	2.7	143	85.1
Community of Independent States (in Asia)	199.8	0.5	72.5	1.2	0.6	0.1	0.3	8	67.4	1.3	930	9.0
Arab States (in Asia)	466.9	1.1	93.1	1.5	0.6	0.1	0.1	6	3.6	0.1	38	161.0
Other Asia	1846.3	4.3	685.5	11.4	17.7	2.4	1.0	25	198.4	3.8	289	89.4
Oceania	567.4	1.3	29.8	0.5	8.5	1.1	1.5	287	71.4	1.4	2399	119.7
Other Selected Countries/Regions (2000 or closest year)												
OECD Countries (All)	24549.3	56.7	1112.2	18.5	599.7	80.4	2.4	539	3147.8	59.7	2830	190.5
France	1426.5	3.3	58.6	1.0	31.4	4.2	2.2	557	160.4	3.0	2737	195.8
Germany	2062.2	4.8	82.1	1.4	52.9	7.1	2.6	646	255.3	4.8	3109	207.0
United Kingdom	1404.4	3.2	59.5	1.0	27.0	3.6	1.9	454	158.7	3.0	2667	170.3
United States of America	9612.7	20.5	278.2	4.6	265.3	35.6	2.8	953	1114.5	21.1	4006	238.1
Community of Independent States (All)	1542.8	3.6	282.9	4.7	13.4	1.8	0.9	47	702.0	13.3	2481	19.1
Russian Federation	1092.6	2.5	146.2	2.4	10.8	1.4	1.0	74	506.4	9.6	3464	21.3
Arab States (All)	1069.2	2.5	270.4	4.5	1.6	0.2	0.2	6	33.6	0.6	124	48.3
Argentina	449.1	1.0	36.6	0.6	2.0	0.3	0.4	55	21.6	0.4	591	92.9
Brazil	1182.0	2.7	168.0	2.8	10.5	1.4	0.9	62	55.1	1.0	328	190.0
South Africa	306.6	0.7	42.1	0.7	2.1	0.3	0.7	50	13.0	0.2	309	163.1

[1]Purchasing power parities

Source: UIS estimates July 2003

The need for a regional approach to global developments

A global comparison

As can be seen from the Table, global gross expenditure on R&D (GERD[7]) rose to an estimated $PPP 746 billion in 2000[8], up from $PPP 547 billion in 1997. Even in the absence of a relevant all-world price deflator, the volume of R&D investment has increased in absolute terms nearly everywhere – if at varying rates – and in any event much faster than the stock of researchers, up only slightly from 5,189,000 to 5,275,000 (full-time equivalent, FTE) over the same period.

The gap between developed and developing regions

If we may begin on a positive note, there are signs that some of the 'gaps' between developed and developing regions may be shrinking little by little: between 1997 and 2000, the share of GDP of the developing countries increased by some 4% to approximately 43%, while their share of world GERD rose from just under 16% to 20%. R&D personnel from the developing world carry even more weight on the world scene: 28% of the total. This figure should be compared with population size. Population growth continued over the same period and, in 2000, the developing countries accounted for 79% of the world population (see Figure I), as compared to slightly less than 78% three years earlier.

It should be noted in passing that the very notions of 'developed' and 'developing' are increasingly blurring the true picture. The positive developments are to a large extent concentrated in a few regions or even a few countries of the Commonwealth of Independant States (CIS). And grouping some of the very low-income CIS countries as 'developed' when Singapore, the Republic of Korea and the like are still 'developing' shows that statistically meaningful conclusions are better drawn at a more disaggregated level.

What one can say is that the share of the traditional 'big-spenders' on R&D, namely Europe, North America and Japan (the former Union of Soviet Socialist Republics (USSR) having slipped from this group) is diminishing as the circle of countries contributing considerably – and increasingly so – to GERD and R&D personnel widens.

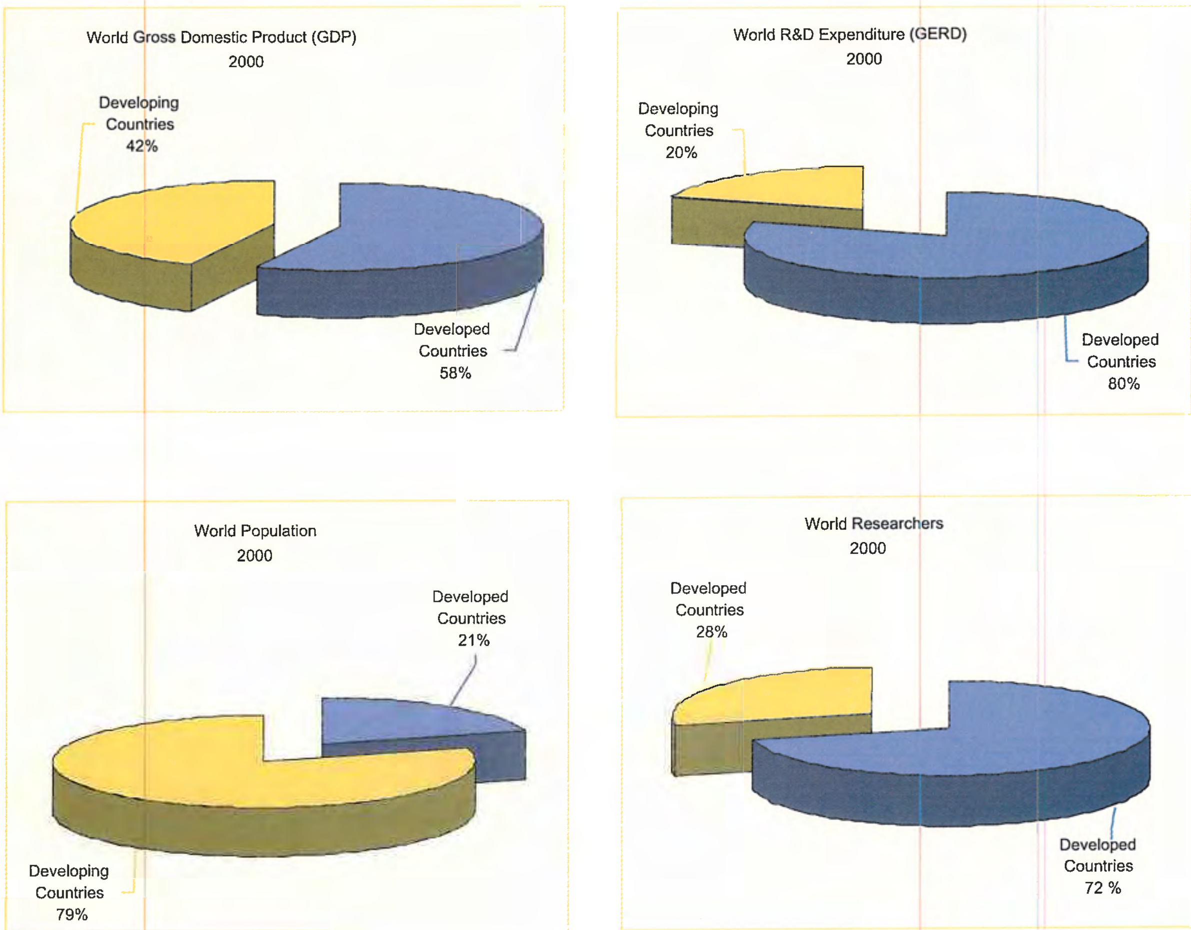
Even if we only discuss 'inputs' to R&D in the present study, it is worthwhile noting that most of the commonly used 'output' indicators (bibliometrics, patents, international high-tech trade) mirror a similar phenomenon.

[7] Gross domestic expenditure on R&D (GERD) covers the total amount of money directly spent on R&D in a given country in a given year, independently of how this R&D has been financed. GERD represents (following the OECD Frascati practice) the sum of all R&D reported by the performing actors in the country: industry (not only manufacturing but also other firms and service branches), in government agencies and other public laboratories, in universities and similar higher education institutions, and in private institutes. National GERD neither covers expenditure for R&D performed abroad nor R&D supported at home, for instance via direct or indirect fiscal incentive schemes.

[8] The afore-mentioned GERD figures are still somewhat underestimated, given that defence R&D expenditure is not always included in the data reported to UNESCO and the OECD and, furthermore, that some important international mega-science programmes (space, nuclear) are also excluded. Moreover, although countries are expected to include in their research statistics R&D in the social sciences and humanities, they do not always fully comply.

FIGURE 1

World GDP in 2000, population and R&D resources (expenditure and personnel)



Source: UIS estimates July 2003

Trends in investment in R&D

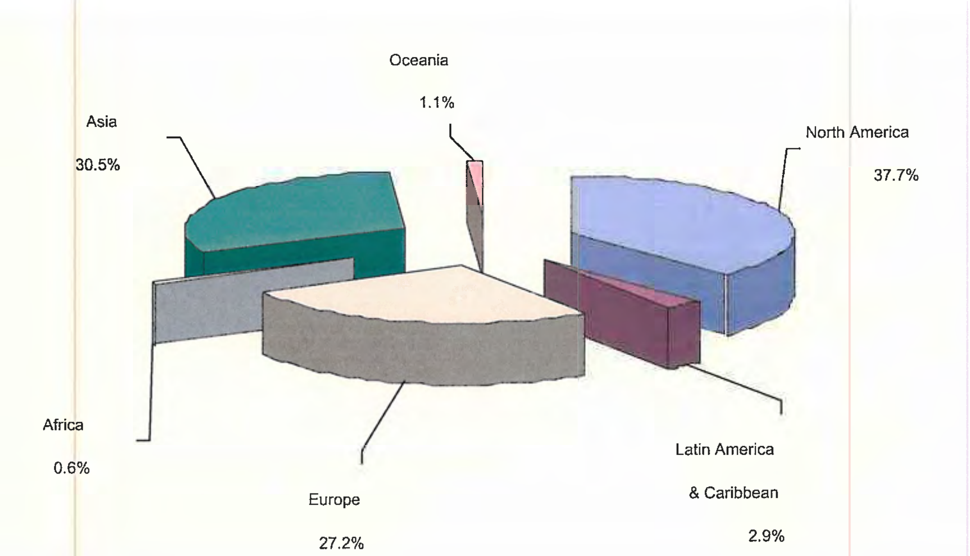
Although there has been a decline in the share of global GERD over the past three years in North America (down from 38.2% to 37.7%), the European Union (down from 25.2% to 23.4%) and Japan (down from 15.2% to 13.2%), the triad still dominates world GERD. The only region to see a progression in its participation in world GERD is Asia; its share rose from 27.9% in 1997 to 30.5% three years later, a result all the more impressive in light of the downturn in Japan's own world share of GERD.

If we dwell for a moment on Japan, it is interesting to note that, even if growth in expenditure on R&D levelled off in Japan during the period under study, it still progressed at a faster pace than the economy as a whole (GDP rising only slightly from $PPP 3000 billion to $PPP 3151 billion). As we have seen in the previous paragraph, the increase in GERD (up to $PPP 99 billion from $PPP 83 billion) was not sufficient to prevent a slight erosion in Japan's share of world GERD.

The rise in Asia's participation in GERD is explained by significant growth in the world shares of China (6.7% as compared to 3.9% in 1997) and the 'dragons' (from 4.9% to 6.5%). These countries represent a dramatic progression in investment in R&D. In the case of China, the trend is accompanied by sustained strong economic growth, with GDP increasing from $PPP 3543 billion in 1997 to $PPP 5029 billion (still at current prices) only three years later, a remarkable performance. For the purposes of comparison, GDP rose in the USA over the same period from $PPP 7511 billion to $PPP 8868 billion. The leap in GERD for China is equally spectacular: from $PPP 21 billion to $PPP 50 billion. With $PPP 48 billion, the 'dragons' have now fallen slightly behind China in terms of R&D investment but this amount still represents a significant increase from just under $PPP 27 billion in 1997. The 'dragon' countries have managed to withstand the financial crisis of the late 1990s and chosen to increase massively investment in R&D, despite limited growth in GDP (from $PPP 2323 billion to $PPP 2866 billion).

FIGURE II

World R&D expenditure (GERD) in 2000 by economic regions



Source: UIS estimates July 2003

Turning to India, we find that its world share of GERD actually dropped slightly between 1997 and 2000 from 2.0% to 1.6%. National investment in R&D (up from just under $PPP 11 billion to $PPP 12 billion) failed to keep pace with healthy growth in GDP (from $PPP 1530 billion to $PPP 2242 billion). This trend may be reversed in coming years. The Government of India has since augmented research spending and plans further increases (see p. 15).

Within Europe, the Russian Federation's share is up to 1.4% from 1.0% and Central and Eastern Europe has progressed from 1.0% to 1.2%. The accession of 10 countries to the European Union in 2004, including Poland and Hungary, will naturally bolster the European Union's world share.

Latin America and the Caribbean, the all-African continent and Oceania still only make a modest contribution to world GERD and their roles appear in decline (from 3.1% to 2.9% in Latin America, from 1.3% to 1.1% in Oceania and from 0.7% to 0.6% in Africa). In the Latin American and Caribbean group, about half the estimated R&D effort may be attributed to Brazil; for its part, South Africa accounts for broadly the same share as the remainder of the entire African continent.

Two groupings of countries in our study cross the major continents. The Arab states stretch over parts of Africa and Asia, and the CIS – the former USSR – over Europe and Asia. Whereas the Arab states' already small contribution to world GERD has declined in relative terms from 0.4% to 0.2%, a small expansion is observed in the CIS, from 1.5% to 1.8%, essentially underpinned by the recovery of the Russian Federation after a decade of absolute decline or, at best, stagnation. Nearly 85% of overall Arab GERD was performed in the following seven countries in the late 1990s: Egypt, Jordan, Kuwait, Morocco, Saudi Arabia, Syria and Tunisia, the fifteen remaining states of the Arab League together accounting for the remainder.

In 1997, nearly 85% of all R&D performed around the world could be credited to the Member countries of the OECD. This share had dropped to around 80% by 2000, a decline explained by the retreating shares of North America, the European Union and Japan.

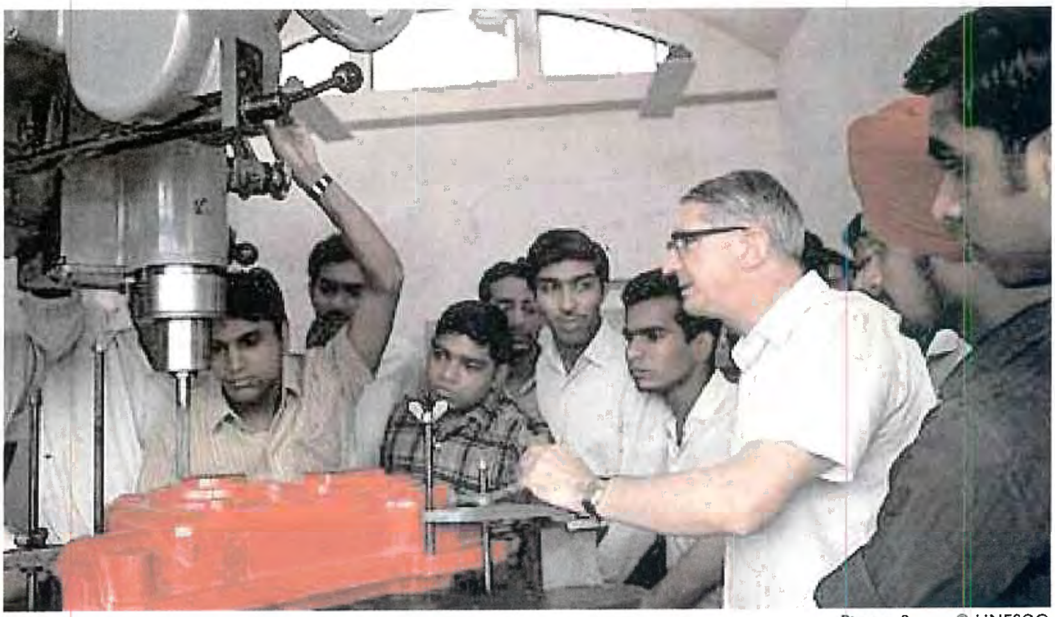
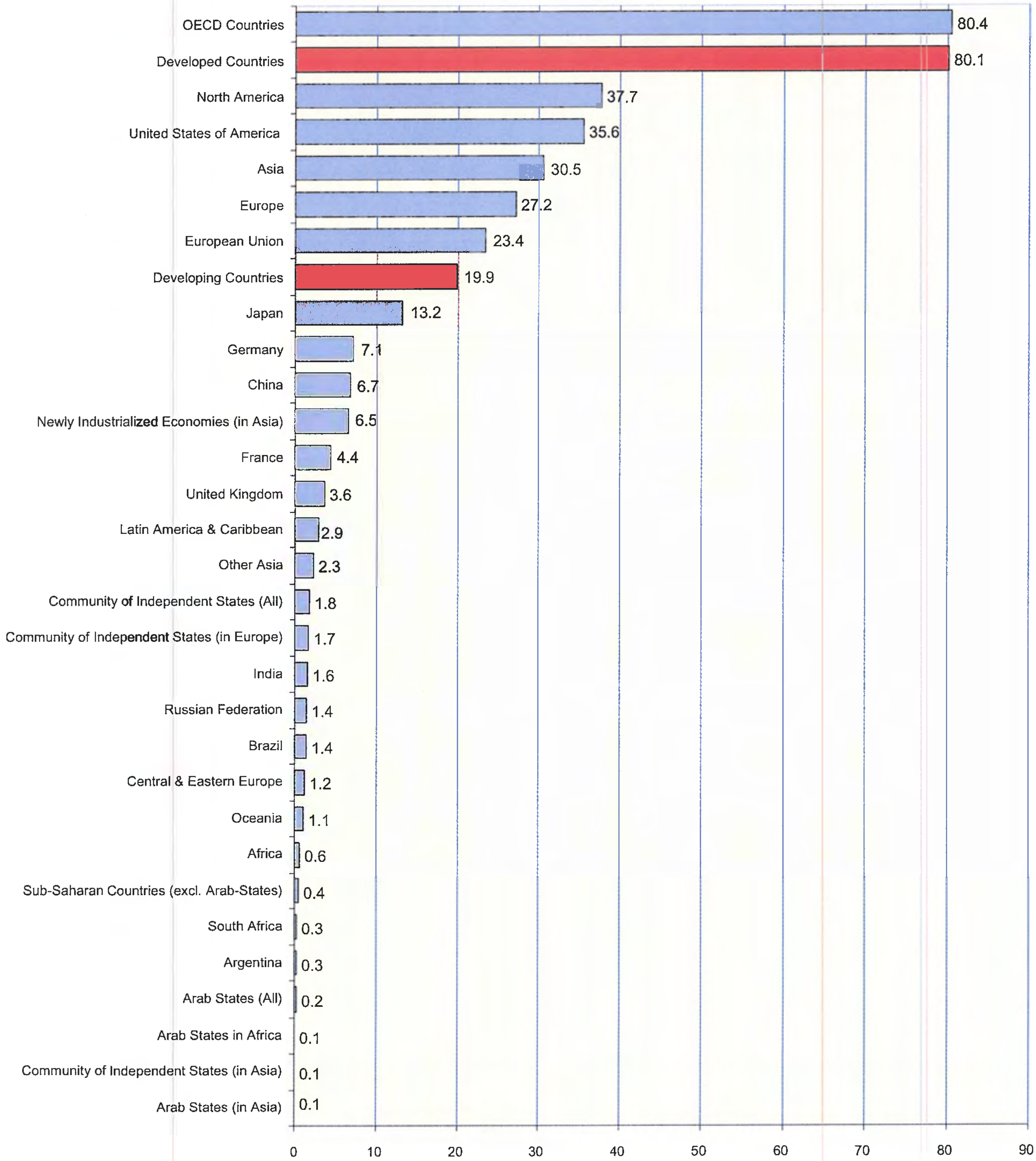


Photo: Satyan © UNESCO

FIGURE III

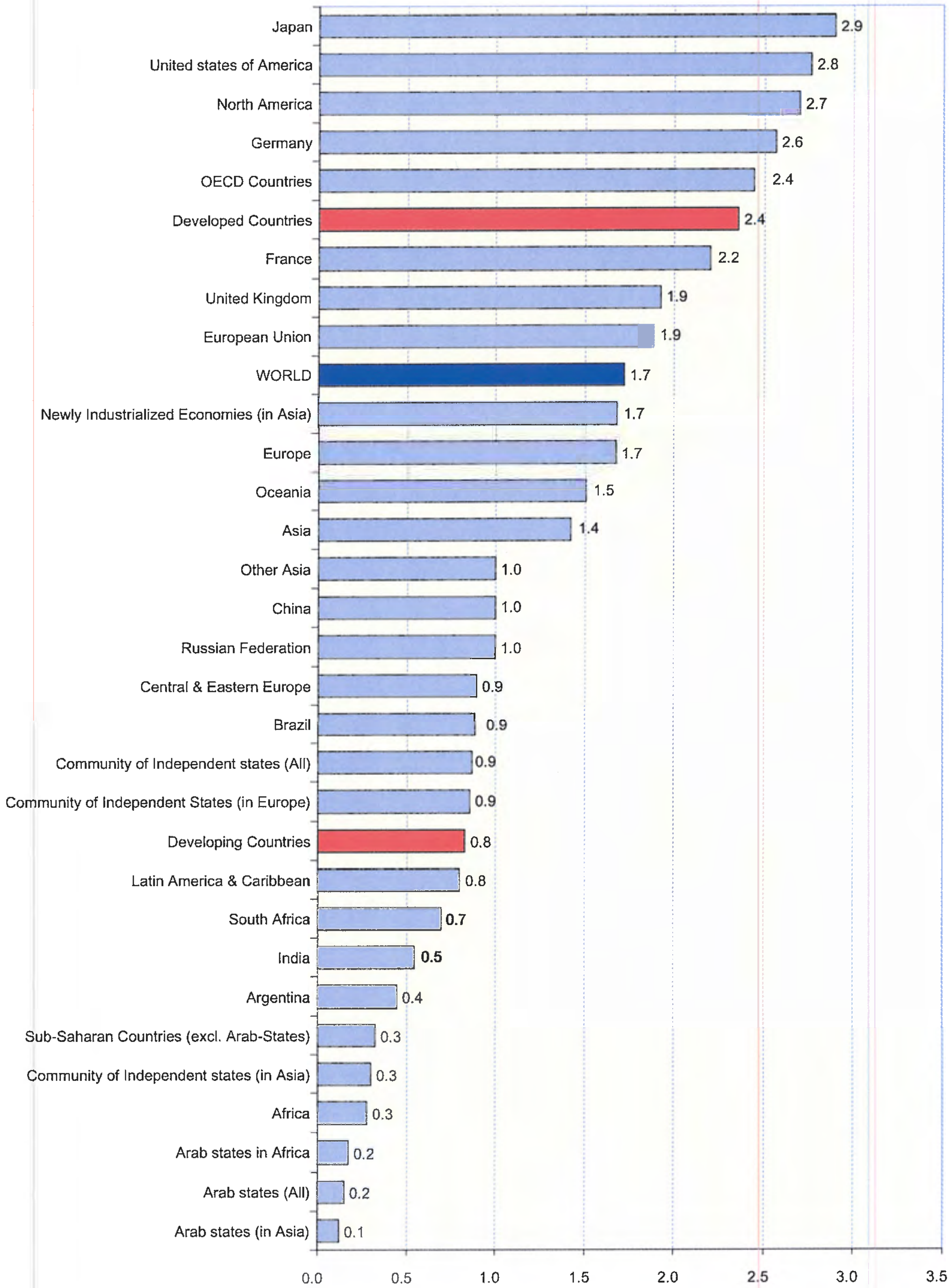
World R&D expenditure (GERD) in 2000 by principal regions/countries (%)



Source: UIS estimates July 2003

FIGURE IV

GERD as a percentage of GDP by principal regions/countries in 2000



Source: UIS estimates July 2003

Comparing financial resources

The most commonly used indicator

GERD as a percentage of GDP is the most commonly used indicator for international comparisons and for defining national policies for S&T. High-income countries usually spend considerably more than 1.5% of GDP on R&D and even up to 3% in some cases, a figure which is now the European Union's policy target for 2010. Still higher ratios are observed in a number of much smaller economies, such as Israel (4.4%) and Sweden (3.8%). India has set itself a target which would place it among the nations of the world which devote the greatest share of GDP to R&D: it plans to hoist research spending to 2% of GDP by 2007, according to a national policy document published in 2003. Indicative of India's commitment, GERD had already climbed to 1.08% of GDP by 2002.

In 2000, approximately 1.7% of world GDP was devoted to R&D, compared to 1.6% in 1997 (see Figure IV). The all-OECD ratio for 2000 was around 2.4% and that of the European Union approximately 1.9%, compared to 2.2% and 1.8% respectively in the previous analysis. Within the group of OECD countries, the median GERD/GDP ratio hovered around 1.8%, approximately the level of Canada. The great majority of countries in the world, however, still spend only a tiny fraction of GDP on R&D. For most of these, the GERD/GDP ratio was even smaller in 2000 than in 1997.

Spending on R&D in Latin America and the Caribbean broadly represented some 0.6% of the region's GDP in 2000, an increase of one decimal point over the previous study, with a median intensity of around 0.27% (the level of Costa Rica). Brazil reported the highest GERD/GDP ratio for Latin America (just under 0.9% in 1999), closely followed by Cuba (0.8%).

Be it north or south of the Sahara, Africa remains by far the least R&D-intensive of the continents. Sub-Saharan Africa allocates only 0.3% of its resources to R&D, the most R&D-oriented country being South Africa (0.7%). The Arab states devote only 0.2% of their resources to R&D. This low figure merits a more detailed look to ascertain to what extent the overall Arab GDP is inflated by the values of important petroleum production figures (although not all the states concerned are oil producers). In point of fact however, the presence of researchers from the Arab region, albeit negligible by international standards, is still about three times higher (0.6%) than its share of world GERD.

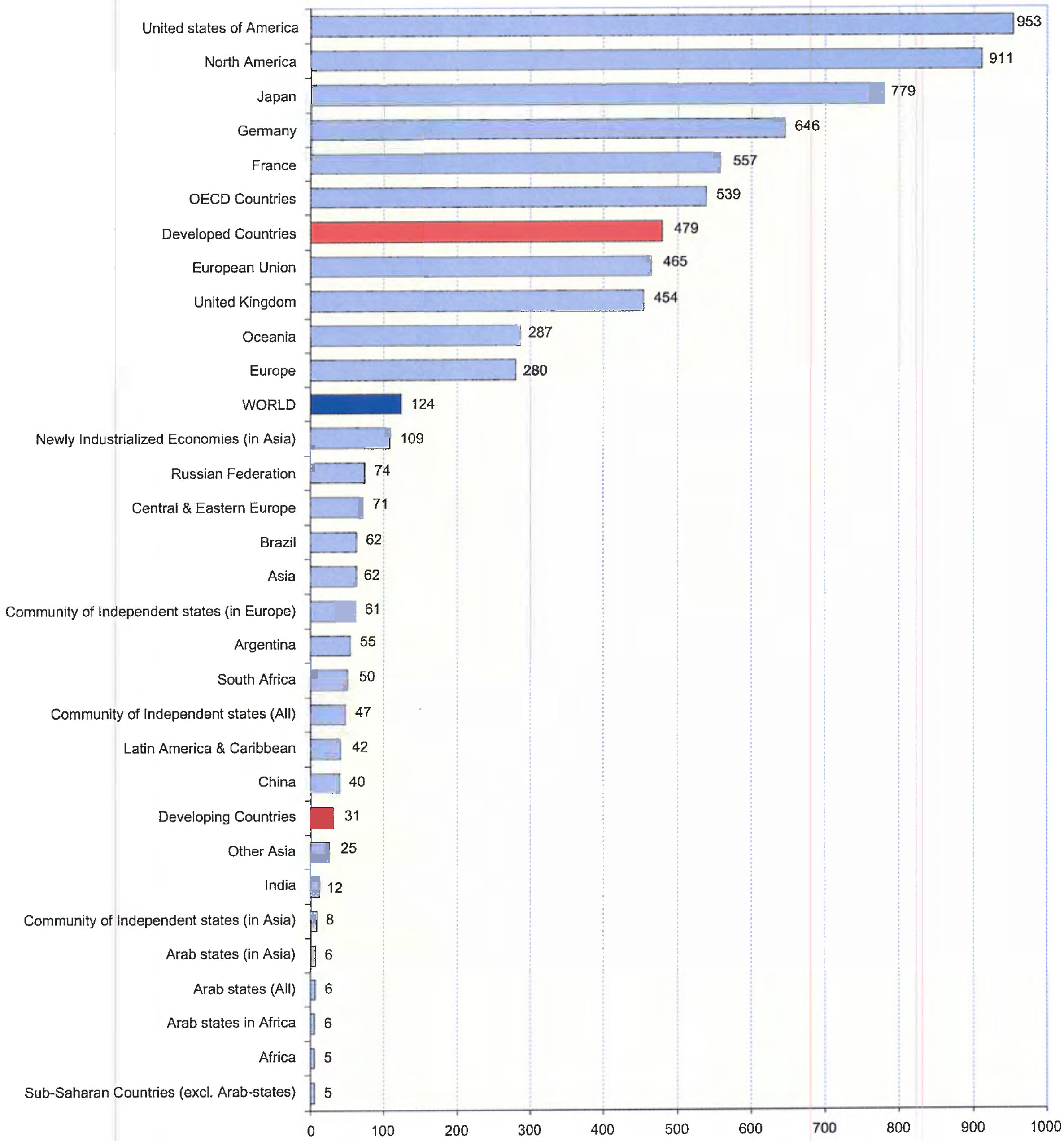
Regional ratios are, of course, directly biased by the weight of the major countries (Brazil, South Africa, China, Japan, etc.), which can cloak the reality of other countries in the same region.

GERD per capita

Although GERD as a percentage of GDP is the better indicator for reflecting the share of income invested in R&D, the GERD per capita indicator has the virtue of showing how far a country still has to go to rival with the world's most prosperous states; for example, despite the fact that China is matched by few other countries in terms of overall investment in R&D, it will need to make a huge

FIGURE V

R&D expenditure (GERD) per capita in 2000 (ppp US$)



Source: UIS estimates July 2003

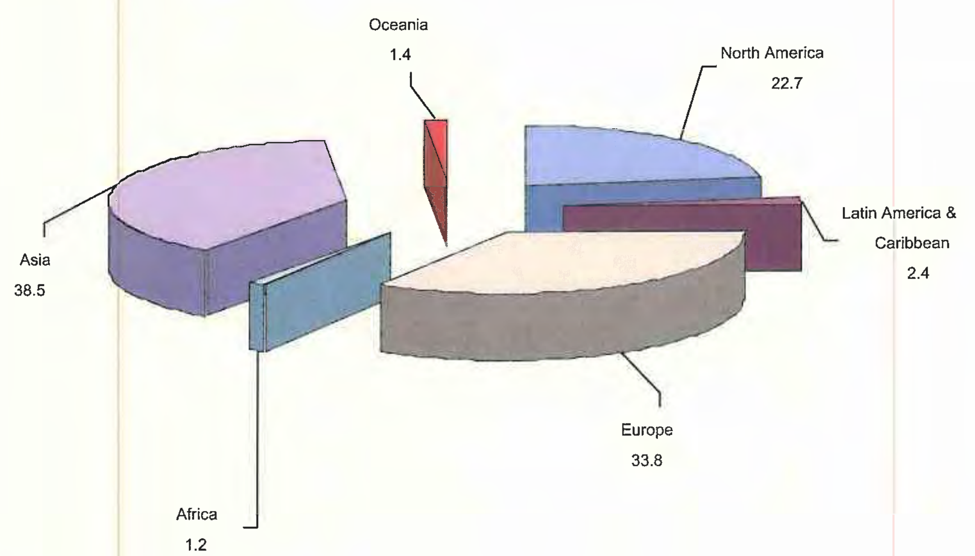
effort to narrow the gap with the USA or Japan: China spends just $PPP 40 on R&D per capita, compared to the $PPP 953 per capita in the USA and $PPP 779 per capita in Japan.

More than any other indicators in this study, the figures for R&D expenditure per capita of the world population should be taken as no more than an order of magnitude, due to very probable weaknesses in both the broad nominators and the denominators, which are likely to be greater the larger the regions concerned. In other words, the figures in the Table are certainly much more plausible at the level, for instance, of individual countries or for well-defined regions (such as the OECD or the European Union) than for the globally estimated breakdowns between the developed and developing countries. These data, however, undoubtedly provide some indication of disparities in the intensity of R&D in different parts of the world: Africa and the Arab States spend approximately $PPP 6 per capita on R&D, compared to $PPP 910 for North America and $PPP 465 for the European Union. Although Latin America and the Caribbean devotes around $PPP 40 per capita to R&D, Brazil's level of investment is closer to that of all-Asia ($PPP 62). The dramatic North–South distortions revealed by this and preceding indicators become even larger when one realizes that some countries still classified as 'developing' should be referred to as 'developed' in terms of income.

In 2000, a global average of $PPP 124 was spent per capita on R&D (Figure V). If the difference in investment per capita between the developing and developed countries remains glaring, the ratio has narrowed somewhat, from 1:18 in 1997 to 1:15 in 2000. The reason for this lies almost exclusively in the huge increase in Chinese investment in R&D (see above).

FIGURE VI

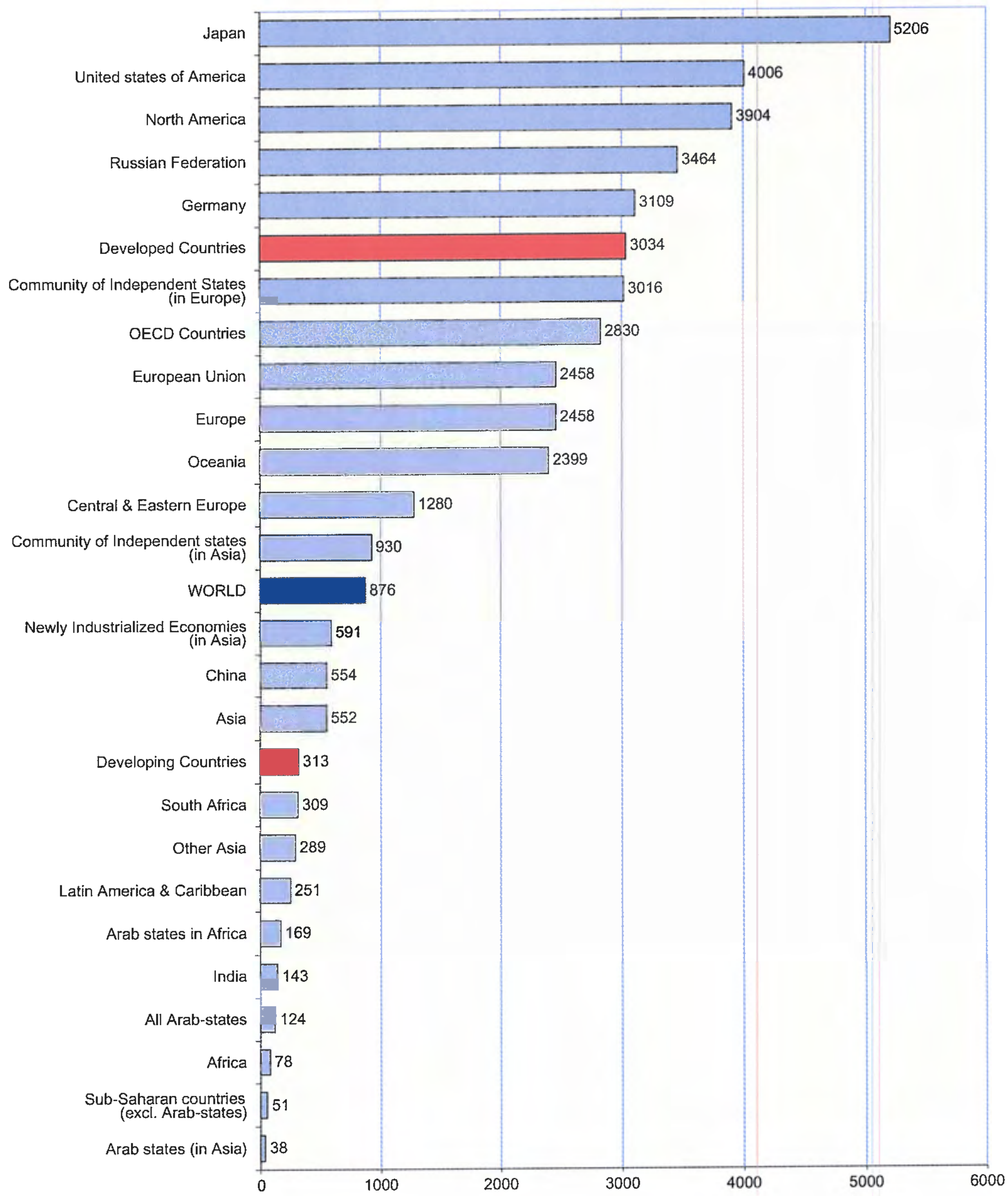
World researchers by economic regions in 2000 (%)



Source: UIS estimates July 2003

FIGURE VII

Researchers per million inhabitants 2000, by principal regions/countries



Source: UIS estimates July 2003

Standing up to be counted

Numbers of scientists and engineers

Statistics show that nearly 5.3 million full-time equivalent research scientists and engineers (RSE[9]). were engaged in R&D around the world (see Table) in 2000. This reflects an increase of less than 2% over the previous study, a far less vigorous progression than that for GERD over the same period. North America and the European Union contribute a larger share of world expenditure than they do world personnel. (Figure VI). This situation is reversed in the case of the Russian Federation, which contributes 9.6% of all researchers but only 1.4% of world GERD. Similarly, China represents 13.2% and 6.7% respectively.

If the numbers of RSE in the world increased little between 1997 and 2000, it is evident that the share of the South is rising. Again, the rise is most apparent in China and the 'dragon countries'. These countries are on a par with Argentina and far outstrip India for this indicator.

Even if the general situation of the developing countries remains far from satisfactory, there are some encouraging signs in the growing numbers of scientists and engineers. Earlier UNESCO estimates had suggested that, around 1985, the developing countries represented only some 12% of total RSE, a figure that had climbed to 15% by 1990. Even if the 28% ratio for 2000 may be explained by better data coverage, it no doubt also reflects a real rise in the volume of RSE in the developing regions, along with steadily growing R&D expenditure. This said, much of the growth in total numbers of researchers reflects a context of rapid population growth (see next section).

Researchers per million inhabitants

The researchers per million inhabitants indicator is useful for determining the representativity of RSE within a given population over time, since it adjusts to population growth.

There were some 875 RSE per million inhabitants worldwide in 2000, down from 985 in the previous study. This overall decline is explained by the rapid population growth in the developing countries, for which the number of RSE fell from 347 in 1997 to 313 per million in 2000. The indicator remains unchanged in the developed regions (3030) over the same period. Once again, the data point to a very low presence of RSE in the Arab states (124 per million) and above all in Africa (78 per million) (Figure VII).

With some 5206 RSE per million inhabitants, Japan is the most R&D-intensive of the major players in R&D, outstripping both the USA (4006) and the Russian Federation (3464).

The large disparities between and within regions are again apparent. The highest regional ratio, that for North America (3900), is some 60% greater

9 The other principal indicator besides expenditure for the evaluation of R&D effort is that of human resources. The S&T/R&D labour force is defined in terms of research scientists and engineers (RSE), technicians and support staff. Only data for the RSE category are available for our present international comparison. RSE are defined here in accordance with the OECD's *Frascati Manual's* definition, as 'professionals engaged in the conception or creation of new knowledge, products, processes, methods and systems and in the management of the projects concerned". The Manual also suggests a breakdown of the R&D workforce by levels of formal qualification and education. These data are, in principle, expressed in terms of full-time equivalence (FTE) rather than as head counts. This is to take into account the fact that some RSE are only employed part-time in research.

than that for Europe (2460), which in turn is slightly ahead of Oceania (2400). The European figure is nearly five times higher than that for Asia (550) and easily distances Latin America and the Caribbean (250).

As we have seen above, there is no set pattern. If we compare, for example, three groups from three different regions which all share roughly the same population size, namely the USA, the CIS and the Arab States, each will tell a different story. While the number of RSE per million inhabitants in the CIS is just over 60% that of the USA, GERD in the CIS amounts to only 5% that of the USA, reflecting both low GDP per capita and very low salaries. If we now turn to the Arab States where total GDP amounts to two-thirds that of the CIS, we find that the number of RSE per million inhabitants is only 0.5% that for the CIS. Moreover, although GERD in the Arab States is only 12% that of the CIS, GERD per researcher is nevertheless proportionately higher in the Arab States than in the CIS, owing to the fact that low expenditure on R&D is spread among fewer researchers.

GERD per researcher

Calculating GERD per RSE provides us with another frequently used indicator, once again to be handled with kid gloves. Here, both the nominator (GERD) and the denominator (RSE) are, in principle, provided by a single source (or at least estimated according to the same principles). Hence, in contrast to our GERD per capita discussed above, this gauge is hardly hampered by large variations in population figures when it comes to international comparisons. This also explains why the gaps between regions and countries are much smaller for the GERD per RSE indicator than for the GERD per capita indicator discussed above (Figure VIII).

Approximately $PPP 140,000 was spent around the world per RSE in 2000 with wide disparities between regions and countries. In 1997, the corresponding sum had been superior to $PPP 100,000 but, once again, owing to the absence of a general R&D deflator, these absolute sums cannot be directly compared even if one may reasonably assume that the growth is real for this indicator.

For the developed countries as a whole, the average annual expenditure per RSE was $PPP 158,000, nearly 60% higher than the average of the developing countries ($PPP 100,000). A little over $PPP 230,000 was spent per RSE in North America, $PPP 190,500 in the OECD and $PPP 184,0000 in the dragon countries, which were slightly ahead of the European Union ($PPP 180,000). GERD per RSE appears to be extremely low in the Arab States, the Russian Federation and in the other CIS states.

Conditions that favour brain drain

It is also useful to look at the figures for GERD per RSE in relation to GDP per capita. The expenses per researcher in a country are actually composed of three elements: his/her own salary, the salaries of technical and support staff, and the average amount of capital and other expenses per researcher, with the total salary element typically representing more than half of the total – and often up to two-thirds or even more – depending on the sector or the discipline of R&D.

Capital and other expenses include instruments which, of course, often have to be imported and are expensive relative to GDP per capita, which makes the overall picture rather complex. Without more detailed data, one cannot formally disentangle these three factors if one calculates only GERD per researcher relative to GDP per capita. Yet, this ratio does provide some interesting perspectives when we compare regions. For one, it turns out to be remarkably equal in OECD countries, varying from 6 to 7, which one could be inclined to take as a certain reference for effective research efforts. The value for Africa, 37, probably indicates in the first place relatively high salaries for RSE compared to the general public, though of course still very low in comparison to researchers in, say, OECD countries. It is less than 3 for the Russian Federation, indicating the opposite, as well as probably a considerably deteriorated working environment. One can clearly translate these data into important policy concerns: the effectiveness of human resources in R&D, the need to avoid brain drain and the position of researchers relative to the general population.

Our figures for GERD per researcher in absolute terms, as well as relative to GDP per capita, therefore do suggest several important issues for governments wishing to build up effective and sustainable R&D systems, in terms of salaries and a proper working environment that provides access to capital equipment, instruments and other research facilities. What is certain is that countries with low RSE salaries, certainly relative to GDP per capita, are the first to fall victim to brain drain.

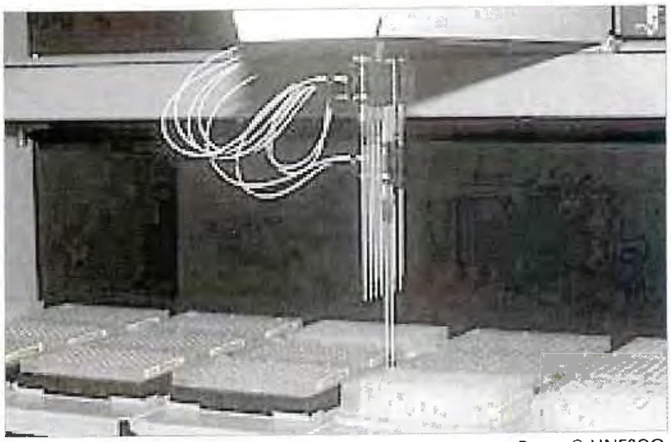
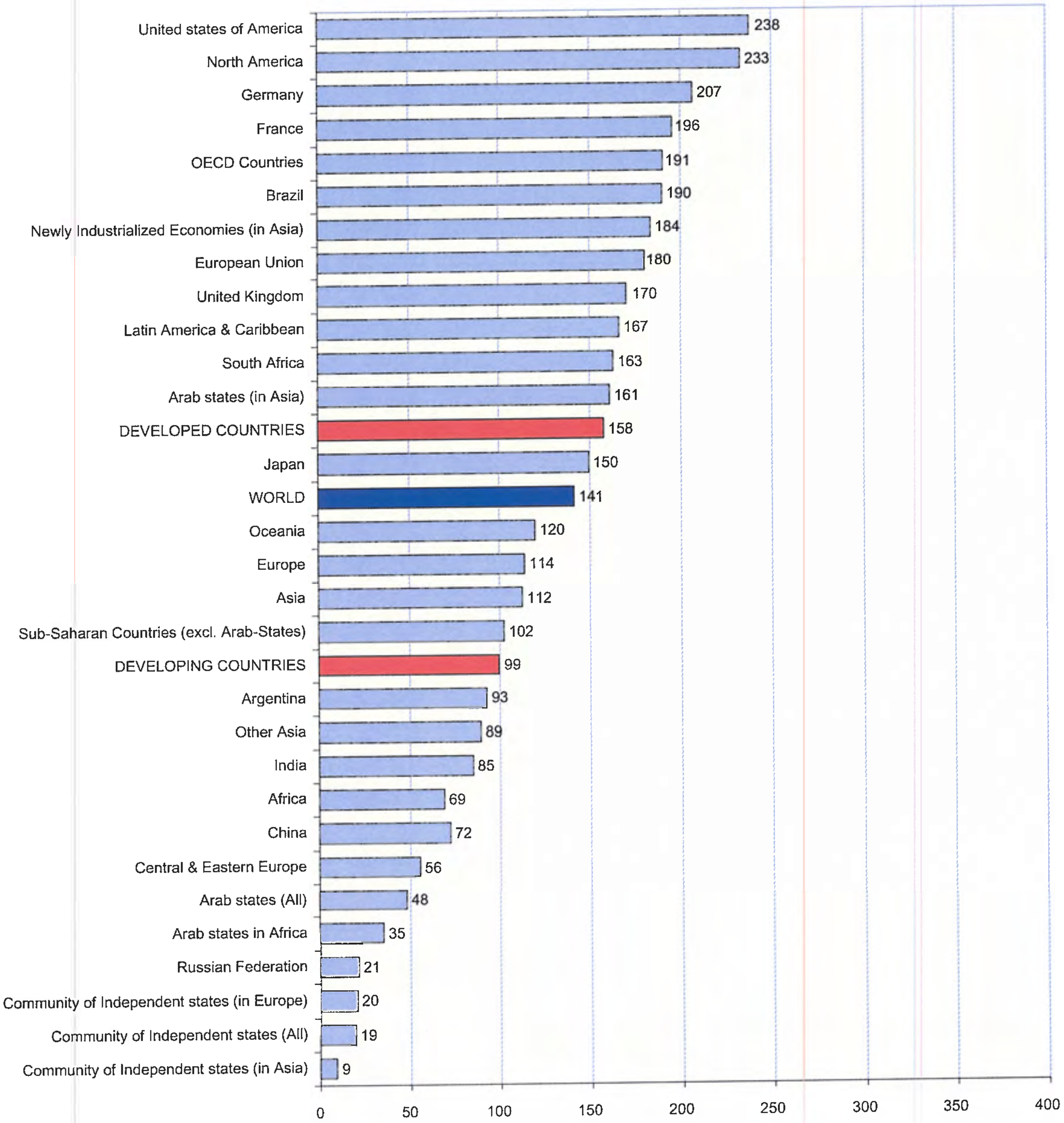


Photo © UNESCO

FIGURE VIII

R&D expenditure (GERD) per researcher in 2000 by principal regions/countries (thousand $ppp)



Source: UIS estimates July 2003

Who performs and who finances R&D?

Who does what?

Data on who performs and who finances R&D reflect the structure of the R&D system in a given country. Here, the data suggest one clear model. While there are differences among countries, almost all OECD countries and, to an increasing extent, China, most of the Asian dragons, the Russian Federation, Brazil and South Africa are moving towards a model where the enterprise sector (private or public) both performs and finances more than 50% (and up to 75%) of R&D. Public funds are the major source of funding for university research, which represents about 15–25% of total GERD. Public sector institutes play a role of varying importance in the performance of R&D. In the Russian Federation and China, for example, they play a large role, that of universities being correspondingly smaller. As for the private non-profit sector, it plays only a modest role throughout the world, although relatively large foundations in some countries do finance a non-negligible part of university research in particular.

Research systems in other regions of the world paint a much more varied picture. They have in common that the government and/or university sector and the public purse play a dominant role in performing and financing R&D respectively.

In several developing countries, but also in a few developed ones, finance from abroad plays an important role. In the case of developing nations, we are usually talking about international donors. In the case of developed nations, it is the European Union and a few foreign enterprises which pay.

One might expect that, as research systems grow and mature, the model referred to above will be followed more and more. One might also expect private enterprises increasingly to set up research activities abroad, including in a wider spectrum of developing countries. This is not yet clearly visible from the current data but will no doubt show up in the future.

The global statistics currently recorded in the UNESCO databases are not yet sufficiently complete to examine, notably for the developing countries, in what sectors national R&D is being performed or by whom they are being financed. More data are available for the OECD countries that – with only one or two exceptions – are all considered to be developed economies. The discussion below on sectoring[10] will therefore be somewhat biased by the weight of the OECD countries in the performance of world R&D (80%) and finance, albeit complemented by information drawn from a number of other regional databases and reports.

Who is performing R&D?

In 2000, 70% of all OECD R&D was performed by the enterprise sector, although the median value for Member countries was closer to 60%. Broadly, 10% of R&D was performed by the government sector (median 14%) and 17% in the higher education sector (median 24%). The remaining 3% was carried

[10] The *Frascati Manual* defines four sectors of R&D performance, finance and employment (the enterprise sector (public and private enterprises and institutes), government sector, higher education sector, private non-profit institutes, plus 'abroad' as an additional sector of finance). Until quite recently, UNESCO used its own definition of sectors but has now aligned itself on the *Frascati Manual* used by the OECD and Eurostat, in the interests of harmonization.

out in by private non-profit institutes. Over the last ten years, this overall picture has changed little, although enterprises have been taking on more R&D to the detriment of the government sector.

As suggested by the medians above, the overall structure is, once again, biased (upwards or downwards depending on the sector) by the weight of a few major countries, notably the USA and Japan. As much as 75% of US R&D is performed by enterprises, a figure closely rivalled by Japan (nearly 72%). It should, however, be noted that a number of much smaller countries are equally oriented towards enterprise R&D. Within the OECD, these are Sweden (78%), Republic of Korea (76%) and Switzerland (74%). Among non-OECD members, we could cite Israel (75%) and the Russian Federation (71%).

Although university research carries some weight in most of the smaller OECD countries, its role is relatively modest (of the order of 15–20% of the total) in several of the principal economies (France, Germany, Japan, UK, USA).

The largest divergences between national R&D systems are to be found in the role of the government sector. Whereas many of the least economically advanced OECD economies, including recently admitted former Eastern Block countries with traditionally agricultural economies and low levels of industrial activity, appear to be drawing heavily on R&D performed by the public sector, a number of other countries are only marginally counting on public sector (not higher education) institutions and laboratories for their R&D. For example, only some 7% of US R&D is performed by public (largely federal) institutions. The distinction between the public or government sector and the higher education sector should, however, not be forgotten. In the US, Federal funds pay for more than one-quarter of the entire national R&D effort, the difference lying in the fact that 60% of overall university research in the USA is financed with federal funds.

Towards the middle of the 1990s, the directly government-controlled sector accounted for broadly half the R&D performed in the all-Arab zone, the so-called 'autonomous' institutions (independent though essentially publicly financed) for another 20%, universities for 30% and enterprises for just 1%.

University research accounts for less than 10% of R&D in the Russian Federation and only 5% in China. About one-third of Chinese R&D and one-quarter in the Russian Federation are performed by the government sector. The weight of industry in performing R&D in China is the same as the OECD median mentioned above (60%). In India, some 70% is performed by the (Federal and State) government sector, a further 27% by enterprises and less than 3% by universities and other tertiary institutions.

With around 39% of the total, higher education accounted for the greatest share of Latin American and Caribbean R&D, ahead of the enterprise (35%) and government sectors.

Within LAC, there is no common structure for the performance of R&D. The government sector leads in four countries (within the 30–62% range topped by Ecuador). University research comes first in another four countries within the ratio of 45–60% (Colombia, Chile, Costa Rica and Bolivia) and the enterprise sector leads in Brazil and Peru (42–45%). Some 40% of Panama's R&D takes place in the private non-profit sector.

In South Africa, enterprises perform 54% of national R&D, universities and other tertiary institutes 34% and government bodies the remainder.

Who is financing R&D?

In the developed regions of the world, private R&D funding is, with few exceptions, dominant and gaining more ground. Conversely, public funds predominate in the developing countries and in much of the former Eastern Block.

At the turn of the century, some 64% of total GERD in the OECD realm was being financed by the private sector, essentially by firms for their own in-house R&D or for R&D carried out on their behalf (in other firms, universities or public laboratories, etc). This share has been rising regularly since the early 1990s when it accounted for only about 55%, an increase explained primarily by the relative stagnation in recent years in public R&D support in a number of the principal OECD countries. Japan and the Republic of Korea currently appear to be the most privately financed countries in the world, with industry funding nearly three-quarters of the national R&D effort in 2000.

The OECD median for industry's share in funding R&D is around 50%; this means that public finance remains quite significant in a number of the most industrialized countries.

Some 28% of OECD GERD was supported by public funds in 2000, compared to broadly 36% in 1991[11]. The OECD median was around 38%. The remainder was balanced by other national sources (4%) and by funds from abroad.

R&D financed from abroad is also increasing everywhere as a result of intense globalization. These cross-border transfers apply above all to R&D projects within multi-domestic groups of firms. They may also be destined for project support and grants from public or private international donor agencies and organizations, such as the United Nations, the European Commission[12], non-governmental organizations, etc. Such funds may be subcontracted in support of specific policy objectives (health, agriculture and food supply, water management, energy, environment...) in the developing regions or be reserved for the promotion of S&T in some of the least R&D-intensive states. Among the OECD countries, one-quarter of Greek GERD was financed from abroad in 2000 and between 15% and 20% in Austria, Canada and the UK, subsidiaries of foreign enterprises accounting largely for the high figure for the latter countries (median around 5%).

Nearly 90% of the all-Arab R&D effort was financed out of the public purse during the second half of the 1990s and only some 2–3% came from the domestic private sectors (still very undersized in most of these countries). The remainder, less than 8%, came from abroad (see above), especially in favour of enterprises in the petroleum sector.

In the Russian Federation, a little more than half of GERD is still publicly supported (55%) and about one-third (33%) comes from enterprises. Whereas the private part appears to be rather stable, the public support share – though regularly fluctuating – shows an overall downward trend that is being substituted by increasing support from abroad (12% in 2000).

The overall financial structure of GERD in China is nearly identical to that reported above for the overall OECD region (i.e. private finance 64%, public sources 33% and funds from abroad 3%).

Government funds represent more than half of GERD throughout Latin America and the Caribbean. At the global level, direct public R&D funds (around 59%), together with the money from the higher education sector (also essentially of public origin), assume some 64% of the total. Funds from enterprises account for 33% and funds

11 Only direct support for R&D is included here (such as payments of contracts, grants, etc), indirect R&D support (such as fiscal incentives, preferential loans etc.) being excluded.

12 The Sixth Framework Programme of the European Union (2002-2006) offers an R&D budget of17.5 billion euros (broadly the same amount in US$).

from abroad approximately 2%. Here again, there are, of course, large structural variations within the region. Brazil and Cuba report support from industry of some 40% (median 23%), whereas private funding appears to be close to non-existent (1–2% only) in countries like El Salvador, Panama and Peru.

Funding from abroad is also an important source of GERD in a majority of Latin-American countries; 46% of GERD in Panama and 23% in El Salvador are financed by overseas funds (median for the region: 8%).

The analysis of African R&D efforts is seriously hampered by the absence of detailed sector statistics for most Sub-Saharan countries. As already stated, South Africa accounts for about half of the continent's expenditure on R&D. National firms currently fund some 50% of South-African R&D, the government sector 33%, other national sources some 10% and foreign funds the remaining 7%. Interestingly, this funding structure differs little from the medians indicated above for the OECD countries.

Several of the most R&D-intensive Arab countries are geographically situated on the African continent and their R&D is, as mentioned, strongly supported by public finance. In the last 10–15 years, R&D resources have seriously dropped in the countries of 'median Africa' and what little R&D is being performed there is essentially project-financed from abroad by international agencies, NGOs and, in exceptional cases, by industrial corporations.

Photo © UNESCO

Appendix

Composition of regions and sub-regions
(countries and territories)

Americas

North America

Canada,USA

Latin America and the Caribbean

Anguilla, Antigua and Barbuda, Argentina, Aruba, Bahamas, Barbados, Belize, Bermuda, Bolivia, Brazil, British Virgin Islands, Cayman Islands, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Former Canal Zone, French Guiana, Greenland, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique (France), Mexico, Montserrat, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, St Kitts and Nevis, St Lucia, St Vincent and the Grenadines, Suriname, Trinidad and Tobago, Turks and Caicos Islands, US Virgin Islands, USA, Uruguay, Venezuela

Europe

Albania, Andorra, Austria, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Faeroe Islands, Fed. Rep. of Yugoslavia, Finland, France, Germany, Gibraltar, Greece, Holy See, Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Moldova, Monaco, Netherlands, Norway, Poland, Portugal, Romania, Russian Federation, San Marino, Slovakia, Slovenia, Spain, Sweden, Switzerland, The Former Yugoslav Rep. of Macedonia, Ukraine, UK.

European Union

Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, UK.

Central and Eastern Europe

Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Estonia, Denmark, Estonia, Federal Republic of Yugoslavia, Hungary, Latvia, Lithuania, Poland, Romania, Slovenia, The Former Yugoslav Republic of Macedonia.

Community of Independent States(Europe)

Belarus, Moldova, Russian Federation, Ukraine

Africa

Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Rep. of the Congo, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libyan Arab Jamahiriya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, St Helena, Sudan, Swaziland, Togo, Tunisia, Uganda, United Republic of Tanzania, Zambia, Zimbabwe.

Sub-Saharan Africa (excluding Arab States)

Africa excluding the Arab States in Africa

Arab States (Africa)

Algeria, Djibouti, Egypt, Libyan Arab Jamahiriya, Mauritania, Morocco, Somalia, Sudan, Tunisia

Southern Mediterranean

Israel, Algeria, Egypt, Lebanon, Libyan Arab Jamahiriya, Malta, Morroco, Tunisia, Turkey, Syrian Arab Republic

Asia

Afghanistan, Armenia, Azerbaijan, Bahrain, Bangladesh, Bhutan, Brunei Darussalam, Cambodia, China, Cyprus, East Timor, Georgia, Hong Kong, India, Indonesia, Islamic Republic of Iran, Iraq, Israel, Japan, Jordan, Kazakhstan, Democratic People's Republic of Korea, Republic of Korea, Kuwait, Kyrgyzstan, Lao People's Democratic Republic, Lebanon, Macau, Malaysia, Maldives, Mongolia, Myanmar, Nepal, Oman, Pakistan, Palestine, Philippines, Qatar, Saudi Arabia, Singapore, Sri Lanka, Syrian Arab Republic, Tajikistan, Thailand, Turkey, Turkmenistan, United Arab Emirates, Uzbekistan, Viet Nam, Yemen.

Newly Industrialized Economies (NIE) in Asia

Chinese Taipei, Indonesia, Republic of Korea, Malaysia, Philippines, Singapore, Thailand.

Industrialized Asia

Japan and the Newly Industrialized Economies (NIE) in Asia.

Comm. of Independent States(Asia)

Armenia, Azerbaijan, Georgia, Kazakstan, Kyrgyzstan, Tajikistan, Uzbekistan.

Arab States (Asia)

Bahrain, Iraq, Jordan, Kuwait, Lebanon, Oman, Palestine, Qatar, Saudi Arabia, Syrian Arab Republic, United Arab Emirates, Yemen.

Other Asia

Afghanistan, Bangladesh, Bhutan, Islamic Republic of Iran, Maldives, Mongolia, Nepal, Pakistan, Sri Lanka, Brunei Darussalam, Cambodia, Democratic People's Republic of Korea, Lao People's Democratic Republic, Myanmar, Viet Nam.

Oceania

American Samoa, Australia, Cook Islands, Fiji, French Polynesia, Guam, Kiribati, Marshall Islands, Nauru, New Caledonia, New Zealand, Niue, Norfolk Island, Papua New Guinea, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu, Republic of Vanuatu.

Developed Countries

Albania, Andorra, Armenia, Australia, Austria, Azerbaijan, Belarus, Belgium, Bulgaria, Canada, Czech Republic, Denmark, Estonia, Faeroe Islands, Finland, France, Georgia, Germany, Gibraltar, Greece, Holy See, Hungary, Iceland, Ireland, Israel, Italy, Japan, Kazakhstan, Kyrgyzstan, Latvia, Liechtenstein, Lithuania, Luxembourg, Moldova, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, San Marino, Slovakia, Spain, St Pierre and Miquelon, Sweden, Switzerland, Tajikistan, Turkmenistan, Ukraine, UK, USA, Uzbekistan.

Developing Countries

World excluding developed countries.

OECD Countries

Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Republic of Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Republic, Spain, Sweden, Switzerland, Turkey, UK, USA.