Measuring progress towards knowledge societies

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 societies and economies. While the process towards knowledge 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 each country acquiring, developing, managing and properly applying appropriate knowledge. Major factors underlying this trend are global institutions (such as the World Trade Organization, the various development banks and the United Nations system) and agreements, as well as the spread of information and communication technologies.

There are, of course, huge discrepancies between countries and (sub-)regions in their approaches to building a knowledge society. The form this process takes 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 we are 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 ensuring a well-educated population. Similarly, equitable and sustainable development can only be achieved if all countries – and men and women everywhere – share in developing and using science.

Measuring and monitoring progress

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 society?

There is a long tradition of collecting data on the efforts of public and private actors in science and technology (S&T), and of turning these data into indicators of a country's performance. We are used to trying to measure not only input – basically investment – in S&T, but also output: what do we get in return for our investment?

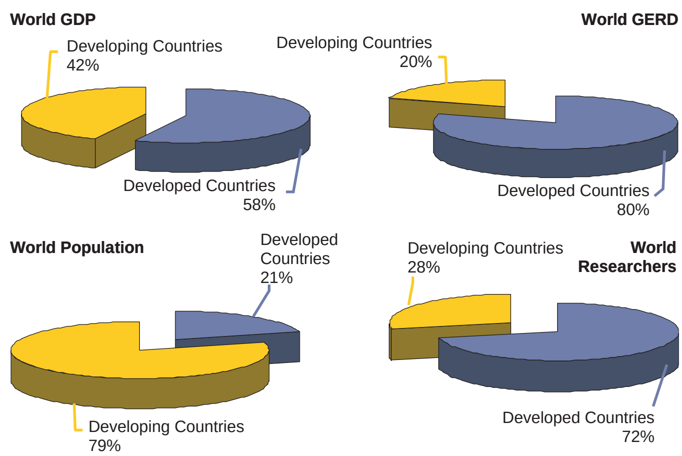
As we come to understand better how companies and societies benefit from S&T, there is a growing need for increasingly sophisticated, complex and broader indicators of the actual processes that lead to prosperity and quality of life. A very useful tool for both policy-making and public debate on a country's performance, for instance, are 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' economy. Even unsophisticated indicators, however, can identify very real trends in development.

A snapshot of global investment in R&D today

Here, we limit our world survey to a few straightforward indicators of input to research and development (R&D) in terms of human and financial investment.

In 2001, the UNESCO Institute for Statistics published a report on *The State of Science and Technology in the World 1996–1997*. An R&D survey conducted since then of UNESCO's Member States, combined with data taken from such international sources as the Latin American Network for S&T Indicators (RICYT), OECD, Eurostat and the World Bank, has enabled the Institute to update these figures to 2000[1]. The following analysis presents no more than a snapshot of emerging trends; a more in-depth study will be published in a forthcoming UNESCO report on science.

Figure I
World GDP, population and R&D resources in 2000



Source: UIS estimates July 2003

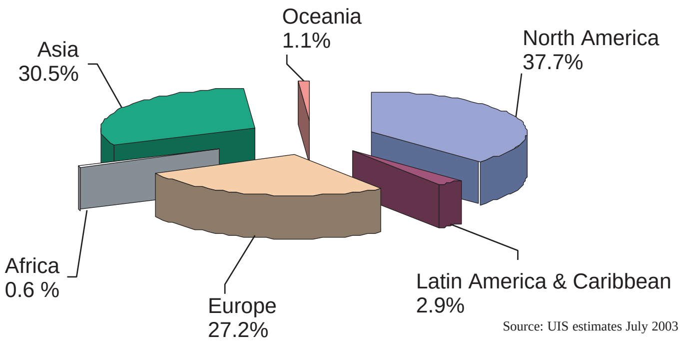


Figure II
Shares of world GERD in 2000
By region

Global gross expenditure on R&D (GERD) rose to an estimated $PPP 746 billion in 2000, up from $PPP 547 billion in 1997. 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 full-time equivalent (FTE) researchers, up by only 1.7% to just under 5.3 million over the same period.

Even if the general situation of the developing world remains far from satisfactory, there are signs that the gap may be closing little by little. Earlier UNESCO estimates had suggested that, in 1985, the developing countries represented as little as 12% of total researchers. By 1997, this figure had climbed to 28%, although it has stagnated since (Figure I). Other gaps seem to be shrinking: between 1997 and 2000, the share of GDP of the developing countries increased by some 3% to approximately 42% and their share in world GERD rose from just under 16% to 20%. This compares with a population size of 79% of the world total in 2000, as opposed to slightly less than 78% in 1997 and 76% in 1985.

Could the notions of developed and developing be blurring the picture?

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. And grouping some of the very low-income countries in the Commonwealth of Independent States (CIS) 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 'input' to R&D here, most of the commonly used 'output' indicators (bibliometrics, patents, international high-tech trade) show a similar phenomenon.

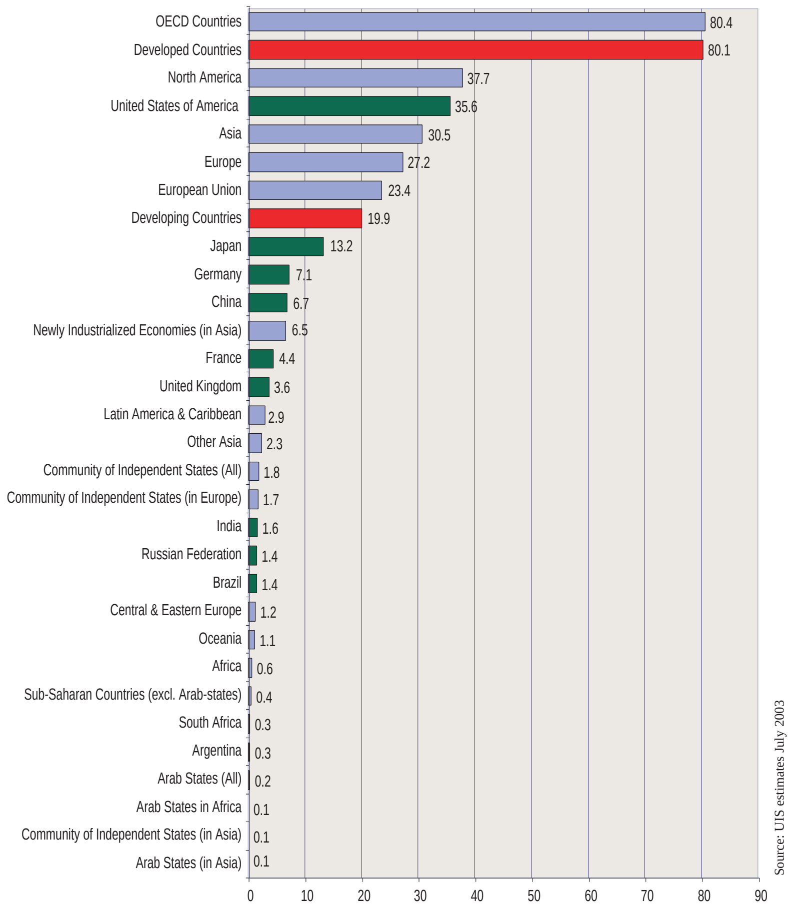
Emerging trends in financial investment in R&D

Although there was a decline in the share of global GERD between 1997 and 2000 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 (Figures II and III). The only region to see its participation in world GERD progress 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 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 above, the increase in GERD (up to $PPP 99 billion from $PPP 83 billion) did not 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

Figure III
Shares of world GERD in 2000. By region/principal countries



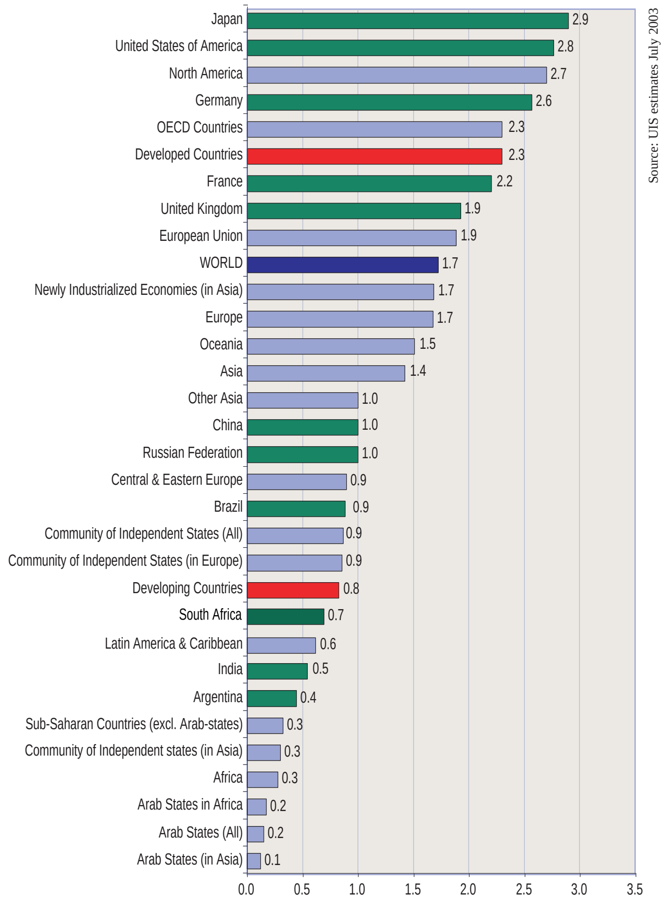


Figure IV
GERD as a percentage of GDP in 2000
By region/principal countries

GDP increasing from $PPP 3543 billion in 1997 to $PPP 5029 billion (still at current prices) only three years later. In 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).

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) has indeed failed to keep pace with healthy growth in GDP (from $PPP 1530 billion to $PPP 2242 billion). However, this trend may be reversed in the next few years. The Government of India has since bolstered research spending and plans further increases (see *Comparing financial resources*).

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 boost 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. (In passing, it is interesting to note that the funding structure of South Africa differs little from the median for the OECD countries: national firms currently fund some 50% of South-African R&D, the government sector 33%, other national sources 10% and foreign funds the remainder.)

Two groupings of countries span two 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.

Several of the most R&D-intensive Arab States are geographically situated on the African continent and their R&D is strongly supported by public finance. In the past 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.

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.

Comparing financial resources

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

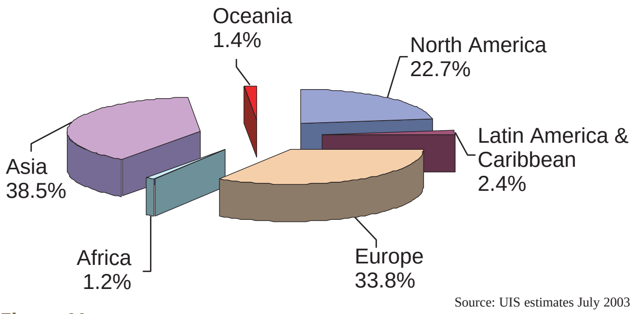


Figure V
World researchers in 2000
By region

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 (Figure IV). The all-OECD ratio for 2000 was around 2.3% 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.

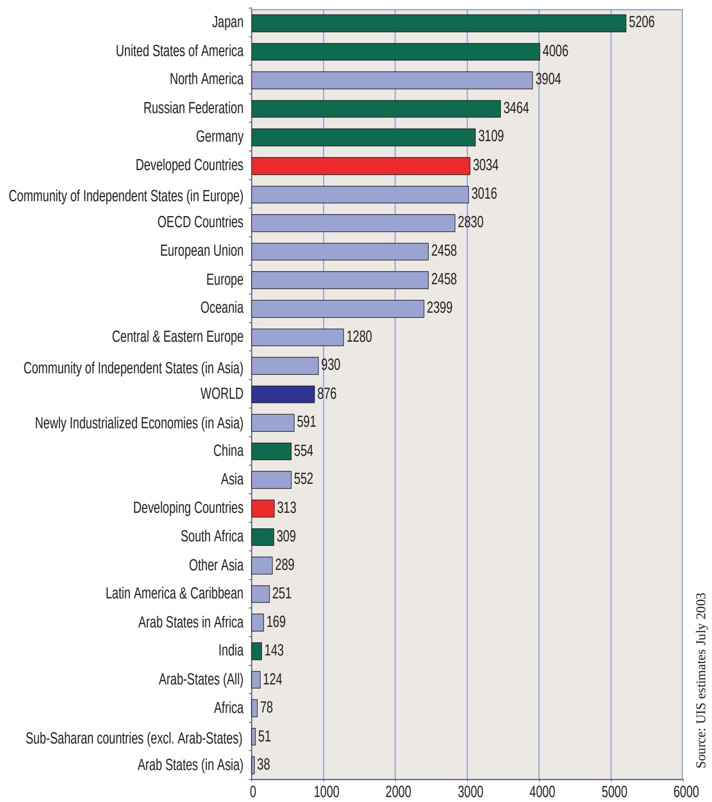
The great majority of countries around the world, however, still spend only a tiny fraction of GDP on R&D. For most of these, the GERD/GDP ratio was even smaller in 2000 than in 1997. There are winds of change in Africa, however, where governments recently reaffirmed their determination to raise spending on R&D to 1% of GDP (see p.8).

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%). The figure for Mexico, the region's only OECD member, was 0.4% in 1999.

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 (in Africa and Asia combined) 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 the region's 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.

Figure VI
Researchers per million inhabitants in 2000
By region/principal countries



Standing up to be counted

There were some 876 research scientists and engineers (RSE) per million inhabitants worldwide in 2000, down from 985 in 1997. This overall decline is explained by the rapid population growth in the developing countries, for which the number of RSE fell from 347 to 313 per million between 1997 and 2000. The indicator remains unchanged in the developed regions over the same period. We are seeing a very low presence of RSE in the Arab States and, above all, in Africa (Figure VI).

Japan is the most R&D-intensive of the major players in R&D, outstripping both the USA and the Russian Federation. Again, there are large disparities both between and within regions.

Conditions that favour brain drain

Expenses per researcher (Figure VII) in a country are 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 more – depending on the sector or the discipline of R&D.

The UIS figures for GERD per researcher in absolute terms, as well as relative to GDP per capita, 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 which pay RSE low salaries – certainly in terms of GDP per capita when compared with other countries – are the first to fall victim to brain drain.

A new phenomenon

In a new twist, we are seeing the phenomenon of 'brain drain' not of people but of jobs: a Deloitte survey of 600 firms in Western Europe and North America in October 2003[3], for example, shows that 14% of these firms have R&D activities in China, a figure that is expected to rise to 20% in three years' time. This trend is reflected in the share of foreign expenditure in total Chinese R&D expenditure.

It can reasonably be expected that private companies will increasingly 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.

There's no turning back

It is clear that the problems of collecting truly comparative data and making sense of them are huge for the many countries which play only a minor role in S&T.

Yet the stakes are high. No single country has succeeded in achieving and sustaining high levels of prosperity and comfort without investing in S&T and exploiting them. The effort therefore must be sustained. As we have seen in the foregoing, even the most straightforward of input data can offer a solid base for policy-making and 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.

Gunnar Westholm[4], Bertrand Tchatchoua[5]
and Peter Tindemans[6]

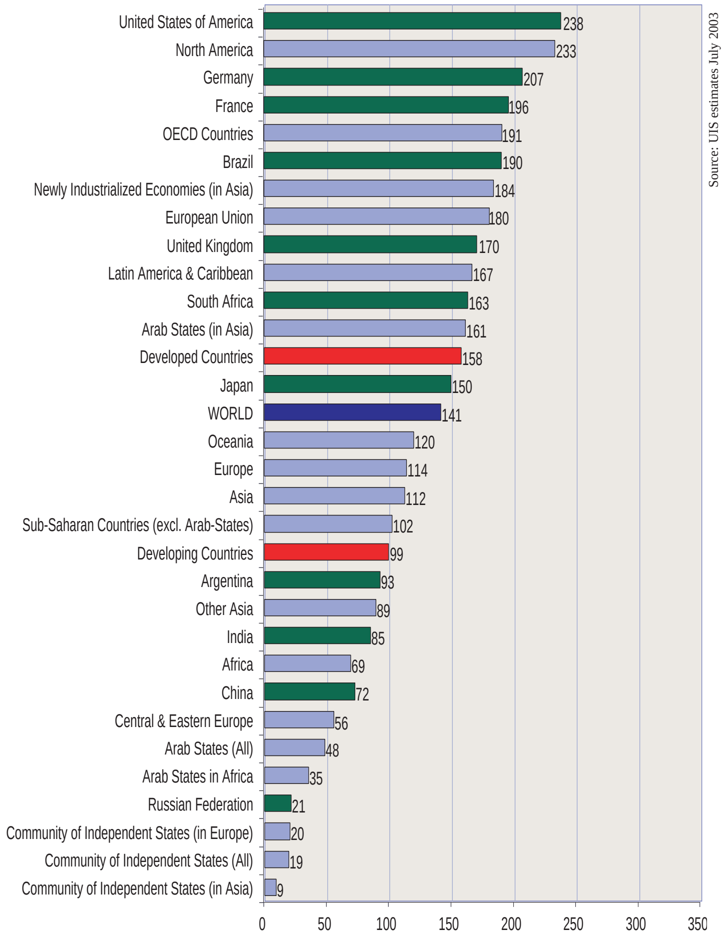


Figure VII
GERD per researcher in 2000 (in thousands $PPP)
By region/principal countries

---

1. Data for some countries may be for 1999. Similarly, data for 1997 may be for 1996 in some cases: www.unesco.org/uis
2. Purchasing power parities
3. www.deloitte.com
4. UNESCO consultant, former OECD statistician
5. Statistician at UIS
6. Science policy analyst, former OECD Megascience Forum Chair

'Science is becoming a world system'

Caroline Wagner, Research Fellow at the non-profit think tank RAND, notes a 50% increase in the number of articles being internationally co-authored in the ten years to 1997, henceforth 15% of the total. 'Science is becoming a world system', she claims. All regions have developed their international collaboration, with the notable exception of the Middle East. As many as 50 countries could now be labelled 'scientifically proficient', according to Wagner, who estimates that the global network of scientific collaboration consisted of 128 core countries in 2000.

Wagner made these observations in her paper entitled *Can the Global Network of Science Contribute to Development?,* presented to the IDRC-UNESCO meeting in April 2003 on *Future Directions for National Reviews of Science, Technology and Innovation in Developing Countries.*

For further information: f.osotimehin@unesco.org