Introduction

Producing knowledge and benefiting from it: the new rules of the game

PETER TINDEMANS

SETTING THE SCENE

There is little doubt that the metaphor most widely used in the present *UNESCO Science Report* is that of a knowledge economy or, as we should say, *knowledge society*. But is it more than a metaphor? Yes, indeed. This introductory chapter will be highlighting some important elements of this new mindset about science and technology (S&T).

Most of the chapters in the present report go beyond updating information on the recent efforts of regions to develop research and development (R&D). The chapters also provide an overview of S&T policies covering a longer period, against the backdrop of what is now perceived as being foremost on the minds of governments, enterprises, research bodies and universities: how to develop a knowledge society.

If we take it for granted that there is real substance to the concept of knowledge societies, there is all the more reason for governments, industry and other actors to take their role in this global movement very seriously. Is this conclusion borne out by the regional reports that follow the present chapter? The answer is that many of these actors are trying, a few are enjoying the first signs of success and all are coming to realize that building up human resources can be accompanied by large-scale problems. This trend will also be addressed in the following pages.

There is another catchword that has gained currency, to the point of even replacing S&T at times, and that is the word 'innovation'. Employed by economists since Schumpeter,[1] it has become the staple food of politicians, industrialists and university managers over the past decade. Many policies on S&T are being restyled into innovation policies. Moreover, the predominance of the private sector in countries that have succeeded in developing and applying S&T suggests that there is a need to rethink the roles of governments, universities and research institutes. We shall thus reflect in this introductory chapter on the role of the private sector and on various corollaries, such as the need for a strong interaction with knowledge institutions and public authorities (the Triple Helix) but also a rethinking of the rules of the game such as in the area of patents. Classical sector-based industrial policies will most likely be more difficult to implement. The scientific profiles of the USA, Europe and Japan can be read as both an indication of the past and a look into the future.

The various chapters in the *UNESCO Science Report* demonstrate that the institutional framework for S&T is going through a period of important adaptation, a fourth theme for this introduction, which will focus on the academic sector. Venerable as they are, universities in most places are nevertheless going to need to reposition themselves to meet the expectations of society, industry and their own students. Autonomy and accountability will be the guiding concepts for rethinking their role. This represents a key task for governments, not least because a strong university system nestled in the midst of a society – one which is equipped to embrace entrepreneurship, open interaction and communication – is vital to countering one of the most serious of problems in a globalizing world: brain drain.

Of course, many more themes emerge from the various chapters that follow. Space constraints preclude covering such issues as the life sciences revolution or sustainability, or what is perhaps the greatest challenge of all, namely whether societies and individuals will be able to find fitting responses to the many deep ethical issues raised by S&T, in a world that is shrinking through globalization – a phenomenon that, by the same token, is laying bare widely differing traditions, points of view and priorities.

HOW DIFFERENT IS A KNOWLEDGE SOCIETY FROM PREVIOUS SOCIETIES?

It is now customary to affirm that knowledge, education, science, technology and innovation have become the

1. Austrian economist who lived from 1883 to 1950.

prime drivers of progress that is itself targeting that most cherished of goals, the knowledge society. Although a much-abused incantation, the concept of the knowledge society carries a very real and practical meaning. It is thus worthwhile to clarify its meaning.

Borrowing economists' parlance, we might say that societies produce goods, services and quality of life – the latter being actually a special category of services. These services result in such highly valued benefits as a sustainable environment, good healthcare and different forms of cultural expression. Government policy underlies the services produced by government. Producing these goods and services requires land, capital goods, human capital, information and knowledge capital, and institutions. These are all termed 'production factors'.

If we now compare traditional societies with modern societies, it becomes evident that both the production factors mentioned above and the products and services that result are heavily transfused with knowledge: not just knowledge in the form of accumulated experience, but science-based knowledge. Take any product or service and the way it is produced, and the differences will stand out. A modern pharmaceutical drug incorporates a lot of advanced pharmaceutical – and often biotechnological and genetic – knowledge and is produced with advanced process machinery. Compare that with medicinal plants, the use of which used to require experiential knowledge only. To feed one person in 1900 required half a hectare of land and more than one year of labour; that same half-hectare now feeds 10 persons on the basis of just one and a half days of labour. The difference lies in the scientific knowledge that went into developing better fertilizers, machinery, seed and crop varieties (the many new Bangladesh rice varieties mentioned in the South Asia chapter of the present report being a nice example), crop rotation schemes and so on. The resulting food often has a high nutritional value coupled with health-improving features.

The cars we drive cannot be produced at a reasonable price without advanced machinery; they themselves embody an accumulation of scientific and engineering knowledge. Nowadays, cars also include information capital, in the form of navigation systems based on the Global Positioning System. 'Producing' a sustainable environment is impossible without advanced ecological simulation models. One could equally take as an example modern communication, transportation or energy infrastructure. Inventing, designing, producing – and often also using – these goods and services requires highly educated, skilled individuals.

Most of the institutions within a society are evidently being transformed as well. Corporations have taken on a new face; financial institutions have evolved to cope with technology-based global instantaneous capital flows. Institutions dispensing education are having to adapt to lifelong learning.

In point of fact, there is an even deeper dimension to knowledge societies. The communal aspect of society living, the mutual understanding of different ethnic, religious or other groups, the public discourse, the dialogue between governments, non-governmental organizations (NGOs), industry and the population at large: all these interactions are increasingly based on complementing, and often replacing, traditional beliefs and inherited views or misconceptions by a more rational, knowledge-based discourse.

It is of course impossible to define the threshold above which a society can be qualified as a knowledge society. It could be said that A.N. Whitehead first sowed the seeds of the concept in *Science and the Modern World*, when he stated that the greatest invention of the nineteenth century was that of the method of invention. This said, the pervasive impact of science is now often quantifiable. And gradual as the process may be, it is now so far advanced in many parts of the world that being part of the globalized world and nourishing corresponding ambitions leaves us no choice but to develop and use production factors 'transfused with knowledge'. Education (and more general learning by individuals and organizations), research and innovation are the key words for this process of 'transfusion'.

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ONLY A FEW NEWCOMERS ARE PRODUCING SCIENCE AND BENEFITING FROM IT

Input into R&D production

The world devoted 1.7% of gross domestic product (GDP) to R&D in 2002. In monetary terms, this translates into US$ 830 billion,[2] according to estimates by the UNESCO Institute for Statistics (December 2004). These global figures conceal huge discrepancies, of course. They reflect the enormous divide in terms of development, prosperity, health and participation in the world economy but also in world affairs in general. These discrepancies are therefore cause for great concern.

The question is, are current trends indicative of a more balanced situation emerging, or do the USA, Europe and Japan continue to dominate knowledge production and remain the ones profiting overwhelmingly from knowledge-turned products and services – in other words, wealth?

It will take a handful of indicators to answer that question. While it is possible to argue at length about the merits of each and every individual indicator, there is no doubt that, where there are wide margins between the scores of regions or countries, these margins do reflect an underlying reality.

Table 1 presents the key indicators for world GDP, population, gross expenditure on R&D (GERD) and personnel in 2002. The shares of North America and Europe[3] in world GERD are on a gently downward sloping path. North America was responsible for 38.2% of world GERD in 1997 but 37.0% in 2002. For Europe, the corresponding figures are 28.8% in 1997 and 27.3% in 2002.

The most remarkable trend is to be found in Asia, where GERD has grown from a world share of 27.9% in 1997 to 31.5% in 2002. As for the remaining regions, Latin America and the Caribbean, Oceania and Africa, these each account for just a fraction of the total, at respectively 2.6% (down from 3.1% in 1997), 1.1% (stable) and 0.6% (stable).

Oceania need not be worried by its small world share, of course. With a population of just 30 million (compared with 766 million for Africa and 505 million for Latin America), Oceania can boast of a GERD per capita and as a percentage of GDP that falls comfortably within the range of the countries of the Organisation for Economic Cooperation and Development (OECD).

However, to unearth where the interesting dynamics are taking place and where there is a genuine cause for concern, we need to look at smaller parts of each of these continents.

In North America, there are some discrepancies and these are naturally of some concern to local and state governments. These governments all vie for public or private investment in R&D but, as this occurs in a completely integrated economy with a highly mobile labour force and a great variety of natural endowments spawning more specialized sub-economies, the standard of living of citizens in the different states is far less varied than regional GERD. R&D is concentrated in just a small number of states: in the USA, for example, 60% of all R&D is carried out in just six states, with California alone accounting for 20%. (See the chapter on the USA.)

With 25 Members since the accession of ten new countries from Central, Eastern and Southern Europe in May 2004, the European Union (EU) now accounts for 90% of European GERD. A further two countries, Bulgaria and Romania, are due to join in 2007. With integration proceeding, the EU ought to conjure up similar, if less pronounced, images of an integrated economy with strongly varying regional concentrations of production factors, including knowledge production factors. That the ten new Member countries no doubt will 'catch up', by attracting greater investment in R&D and generating higher levels of income, is a natural process and does not imply a trend simply towards deconcentration. More worrying from an economic perspective is that one of the underlying issues in the current debate about the future direction of the EU concerns its capacity to accept regional differences, which may be wise economically, but which are politically difficult to swallow. The fact that the R&D budget of the EU represents just 5% of public

2. All US$s in this chapter are PPP $s.
3. Europe here includes notably Russia, Ukraine and Belarus.

Table 1
KEY INDICATORS ON WORLD GDP, POPULATION AND GERD, 2002

	GDP (in billions)	% world GDP	Population (in millions)	% world population	GERD (in billions)	% world GERD	% GERD /GDP	GERD per inhabitant
World	**47 599.4**	**100.0**	**6 176.2**	**100.0**	**829.9**	**100.0**	**1.7**	**134.4**
Developed countries	28 256.5	59.4	1 195.1	19.3	645.8	77.8	2.3	540.4
Developing countries	18 606.5	39.1	4 294.2	69.5	183.6	22.1	1.0	42.8
Less-developed countries	736.4	1.5	686.9	11.1	0.5	0.1	0.1	0.7
Americas	**14 949.2**	**31.4**	**849.7**	**13.8**	**328.8**	**39.6**	**2.2**	**387.0**
North America	11 321.6	23.8	319.8	5.2	307.2	37.0	2.7	960.5
Latin America and the Caribbean	3 627.5	7.6	530.0	8.6	21.7	2.6	0.6	40.9
Europe	**13 285.8**	**27.9**	**795.0**	**12.9**	**226.2**	**27.3**	**1.7**	**284.6**
European Union	10 706.4	22.5	453.7	7.3	195.9	23.6	1.8	431.8
Comm. of Ind. States in Europe	1 460.0	3.1	207.0	3.4	17.9	2.2	1.2	86.6
Central, Eastern and Other Europe	1 119.4	2.4	134.4	2.2	12.4	1.5	1.1	92.6
Africa	**1 760.0**	**3.7**	**832.2**	**13.4**	**4.6**	**0.6**	**0.3**	**5.6**
Sub-Saharan countries	1 096.9	2.3	644.0	10.4	3.5	0.4	0.3	5.5
Arab States Africa	663.1	1.4	188.2	3.0	1.2	0.1	0.2	6.5
Asia	**16 964.9**	**35.6**	**3 667.5**	**59.4**	**261.5**	**31.5**	**1.5**	**71.3**
Comm. of Ind. States in Asia	207.9	0.4	72.6	1.2	0.7	0.1	0.4	10.3
Newly Indust. Asia	2 305.5	4.8	374.6	6.1	53.5	6.4	2.3	142.8
Arab States Asia	556.0	1.2	103.9	1.7	0.6	0.1	0.1	6.2
Other Asia	1 720.0	3.6	653.7	10.6	1.4	0.2	0.1	2.1
Oceania	**639.5**	**1.3**	**31.8**	**0.5**	**8.7**	**1.1**	**1.4**	**274.2**
Other groupings								
Arab States All	1 219.1	2.6	292.0	4.7	1.9	0.2	0.2	6.4
Comm. of Ind. States All	1 667.9	3.5	279.6	4.5	18.7	2.2	1.1	66.8
OECD	28 540.0	60.0	1 144.1	18.5	655.1	78.9	2.3	572.6
Selected countries								
Argentina	386.6	0.8	36.5	0.6	1.6	0.2	0.4	44.0
Brazil*	1 300.3	2.7	174.5	2.8	13.1	1.6	1.0	75.0
China	5 791.7	12.2	1 280.4	20.7	72.0	8.7	1.2	56.2
Egypt*	252.9	0.5	66.4	1.1	0.4	0.1	0.2	6.6
France	1 608.8	3.4	59.5	1.0	35.2	4.2	2.2	591.5
Germany	2 226.1	4.7	82.5	1.3	56.0	6.7	2.5	678.3
India*	2 777.8	5.8	1 048.6	17.0	20.8	2.5	0.7	19.8
Israel	124.8	0.3	6.6	0.1	6.1	0.7	4.9	922.4
Japan	3 481.3	7.3	127.2	2.1	106.4	12.8	3.1	836.6
Mexico	887.1	1.9	100.8	1.6	3.5	0.4	0.4	34.7
Russian Federation	1 164.7	2.4	144.1	2.3	14.7	1.8	1.3	102.3
South Africa	444.8	0.9	45.3	0.7	3.1	0.4	0.7	68.7
United Kingdom	1 574.5	3.3	59.2	1.0	29.0	3.5	1.8	490.4
United States of America	10 414.3	21.9	288.4	4.7	290.1	35.0	2.8	1005.9

* GERD figures for Brazil, India and Egypt are all for 2000.
Note: For Asia, the sub-regional totals do not include China, India or Japan in any of the tables in the present chapter.

Source: UNESCO Institute for Statistics estimations, December 2004.

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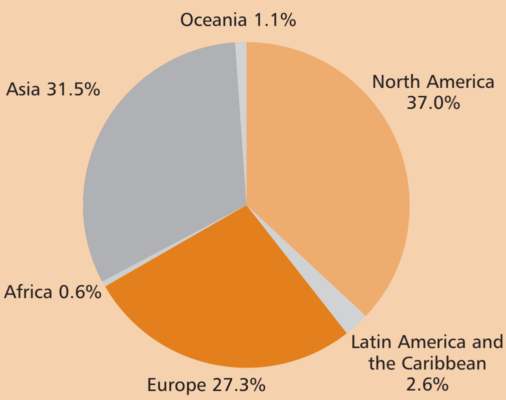
Figure 1
WORLD SHARES OF GERD, 2002
By region



Source: see Table 1.

expenditure on R&D by Member States also demonstrates that there is no such thing yet as a truly European R&D market.

As far as Asia is concerned, it is now very clear that the so-called Newly Industrialized Asian economies, together with China and, to a lesser extent, India have become serious contributors to world GERD and to the stock of knowledge. In 2002, China contributed 8.7% of world GERD, up from 3.9% in 1997. This compared with 6.4% for the Newly Industrialized Asian economies, up from 3.9% in 1997, even if the percentage remained stable between 1997 and 2000. India contributed 2.5% to world GERD in 2000, up from 2.0% in 1997. The complicated political scene and slowly broadening technological base – now firmly rooted in information and communications technology (ICT), space, pharmaceuticals and biotechnology – are taking India along a gently upward-sloping path: the advantage is perhaps that it is easier to maintain a steady pace on a gentle slope than on a steeper climb.

The trend in the number of researchers tends to paint a similar picture to that of financial investment in R&D. Not surprisingly, but still indicative of the new era we live in, there were more researchers in China in 2002 than in Japan and more in the Newly Industrialized Asian economies as a whole than in Germany.

The leading Asian economies share a strong commitment to S&T: the Republic of Korea, Singapore and Taiwan of China devote more than 2% of GDP to R&D. As for China, it is well on the way to realizing its goal of a 1.5% GERD/GDP ratio by 2005. Meanwhile, India has set its own sights on crossing the 2% threshold in the coming years. The world will no doubt witness more sweeping changes in the S&T landscape in the coming decade.

Taking a bird's eye view of the dynamics of S&T production obliges us to deal separately with the Community of Independent States (CIS), made up of the countries of the former Union of Soviet Socialist Republics (USSR) in Europe and Asia. Under Soviet rule, most of these now independent states had built up strong R&D systems, albeit unbalanced ones from an economic perspective.

Since the disintegration of the USSR more than a decade ago, the R&D systems of all these states have become a shadow of their former selves, yet their size still stands out. The proportion of GDP spent on R&D by the Russian Federation, for example, still stands at 1.3%. Moreover, the number of researchers in Russia, 3 400 per million inhabitants, is the third-highest in the world, after Japan (5 100) and the USA (4 400). The downside is that expenditure per researcher amounts to a pittance in the Russian Federation, translating into low salaries and negligible expenditure on equipment, housing and consumables. Added to the still inconclusive restructuring of the Russian R&D system, explained vividly in the chapter on the Russian Federation, this implies poor working conditions. Although the situation definitely seems to be stabilizing and even improving with a slight

Table 2
WORLD RESEARCHERS, 2002

	Researchers (thousands)	% world researchers	Researchers per million inhabitants	GERD per researcher (US$ thousands)
World	**5 521.4**	**100.0**	**894.0**	**150.3**
Developed countries	3 911.1	70.8	3 272.7	165.1
Developing countries	1 607.2	29.1	374.3	114.3
Less-developed countries	3.1	0.1	4.5	153.7
Americas	**1 506.9**	**27.3**	**1 773.4**	**218.2**
North America	1 368.5	24.8	4 279.5	224.5
Latin America and the Caribbean	138.4	2.5	261.2	156.5
Europe	**1 843.4**	**33.4**	**2 318.8**	**122.7**
European Union	1 106.5	20.0	2 438.9	177.0
Comm. of Ind. States in Europe	616.6	11.2	2 979.1	29.1
Central, Eastern and Other Europe	120.4	2.2	895.9	103.4
Africa	**60.9**	**1.1**	**73.2**	**76.2**
Sub-Saharan Countries	30.9	0.6	48.0	113.9
Arab States Africa	30.0	0.5	159.4	40.9
Asia	**2 034.0**	**36.8**	**554.6**	**128.5**
Comm. of Ind. States in Asia	83.9	1.5	1 155.0	8.9
Newly Indust. Asia	291.1	5.3	777.2	183.7
Arab States Asia	9.7	0.2	93.5	66.6
Other Asia	65.5	1.2	100.2	20.9
Oceania	**76.2**	**1.4**	**2 396.5**	**114.4**
Other groupings				
Arab States All	39.7	0.7	136.0	47.2
Comm. of Ind. States All	700.5	12.7	2 505.3	26.7
OECD	3 414.3	61.8	2 984.4	191.9
Selected countries				
Argentina	26.1	0.5	715.0	61.5
Brazil*	54.9	1.0	314.9	238.0
China	810.5	14.7	633.0	88.8
France	177.4	3.2	2 981.8	198.4
Germany	264.7	4.8	3 208.5	211.4
India*	117.5	2.1	112.1	176.8
Israel*	9.2	0.2	1 395.2	661.1
Japan	646.5	11.7	5 084.9	164.5
Mexico*	21.9	0.4	217.0	159.7
Russian Federation	491.9	8.9	3 414.6	30.0
South Africa	8.7	0.2	192.0	357.6
United Kingdom*	157.7	2.9	2 661.9	184.2
United States of America*	1 261.2	22.8	4 373.7	230.0

* India 1998, Israel 1997, United States 1999, United Kingdom 1998, Brazil 2000, Mexico 1999.

Source: UNESCO Institute for Statistics estimations, December 2004.

rise in the budget for R&D, it is too soon to say that R&D is taking off in the Russian Federation.

The situation is much bleaker in the CIS states of Asia. Nowhere in the world is GERD per researcher as low as here, at just US$ 8 900, compared with US$ 200 000 in many developed states and US$ 30 000 in the Russian Federation. Nor are there any signs that the situation is improving in these states.

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Many of the countries from South-East Europe are also still struggling to make a comeback after a turbulent decade. Having built up the same command-economy type of institutions as in the USSR, they suffered economic upheavals similar to those of the CIS states in the 1990s, with hardship compounded by civil war in the case of the former Yugoslav republics.

Unlike in Asia, there is no discernible steady upturn in R&D in Latin America and the Caribbean. On the contrary, there actually seems to be a downturn. The region's share in world GERD has fallen back from 3.1% in 1997 to 2.6% in 2002. Moreover, three countries – Brazil, Mexico and Argentina – account for 85% of the region's GERD, leaving the remainder with average expenditure of no more than 0.1% of GDP – with the small but notable exception of Cuba, at 0.6%.

The situation in Africa is even bleaker. The GERD/GDP ratio is already low, for both the sub-Saharan countries and the Arab states of Africa, at 0.3% and 0.2% respectively, but even that paints a picture that is rosier than reality: South Africa is responsible for 90% of GERD in sub-Saharan Africa and, as we shall see in the chapter on Africa, Egypt and to a lesser extent Tunisia, Morocco and Algeria carry out practically all R&D in the Arab states of Africa. Certainly, there are encouraging signs in a number of countries but, after a prolonged period of disruption, many countries are struggling simply to get back to where they were in the 1970s and early 1980s. On the whole, the situation is still deeply distressing and the distance to travel so far.

What is true for the Arab states of Africa also holds for the Arab states of Asia, albeit to a somewhat lesser degree. A handful of countries account for most of the sub-region's GERD, among them Jordan, Kuwait and Saudi Arabia. Some might argue that the reason for the dismal performance from even the fossil fuel-rich countries lies in their relatively high income per capita. One could counter this argument by saying that the fossil fuel-rich countries could afford to spend much more on R&D but are apparently not sufficiently convinced of the need to invest in a knowledge economy. Yet, no country will be able to achieve and durably maintain prosperity and a high quality of life without using the results of research and ensuring a well-educated population. As the last sentence of the chapter on the Arab region cogently puts it, if the Arab states are to fully develop their potential in S&T, they will need to implement reforms to build societies which promote tolerance, allow freedom of expression, encourage free thinking and respect human rights.

Output

Turning to output of R&D production, the global situation here barely differs from that of input to R&D. It is true that the USA has now been overtaken by the European Union in terms of the number of scientific articles, as we shall see in the chapter on the European Union, but if one limits this survey to publications and citations in the highest impact journals, the USA remains very much in the lead.

That the number of publications funded by the public purse is substantially higher in Europe than in the USA may suggest much greater productivity per researcher but there is actually a simple explanation for this: military R&D comprises more than 50% of public R&D expenditure in the USA but much less in Europe.

It will come as no surprise that the triad formed by the USA, Europe and Japan dominates scientific articles in the world. The share of other regions is usually (much) lower than their GERD shares. Yet, one should also look behind the veil of regional coverage to see how individual countries are faring. Turkey, for example, is making rapid progress (see the chapter on South-East Europe) and will no doubt begin making its presence felt on the world scene a few years from now.

Patent statistics present a stark picture of disparities in the world. Whereas the developing nations account for 22% of world GERD (Table 1 and Figure 1), they represent just over 7% of all patents granted by the United States Patent and Trademark Office (USPTO) (Table 3) and as little as 3% of patent applications to the European Patent Office (EPO) (Table 4). This is to be expected of course, as patents are indicative of a strong, mature business environment where there are marked incentives to innovate. This type of

Table 3
PATENTS GRANTED AT USPTO,1991 AND 2001

	Total 1991	Total 2001	% world 1991	% world 2001
World	**96 268**	**166 012**	**100.0**	**100.0**
Developed countries	94 285	154 999	97.9	93.4
Developing countries	2 215	12 128	2.3	7.3
Less-developed countries	–	8	–	0.0
Americas	**53 848**	**93 321**	**55.9**	**56.2**
North America	53 679	92 988	55.8	56.0
Latin America and Caribbean	194	449	0.2	0.3
Europe	**19 955**	**31 128**	**20.7**	**18.8**
European Union	18 504	29 124	19.2	17.5
Comm. of Ind. States in Europe	–	350	–	0.2
Central, Eastern & Other Europe	1 670	2 193	2	1.3
Africa	**128**	**160**	**0.1**	**0.1**
Sub-Saharan countries	121	146	0.1	0.1
Arab States Africa	7	14	0.0	0.0
Asia	**23 028**	**45 163**	**23.9**	**27.2**
Comm. of Ind. States in Asia	–	9	–	0.0
Newly Indust. in Asia	1 436	9 811	1.5	5.9
Arab States in Asia	10	37	0.0	0.0
Other in Asia	17	58	0.0	0.0
Oceania	**527**	**1 127**	**0.5**	**0.7**
Other groupings				
Arab States All	17	51	0.0	0.0
Comm. of Ind. States All	–	359	–	0.2
OECD	94 667	158 317	98.3	95.4
Selected countries				
Argentina	19	53	0.0	0.0
Brazil	66	149	0.1	0.1
China	63	298	0.1	0.2
Egypt	4	11	0.0	0.0
France	3 154	4 516	3.3	2.7
Germany	7 914	12 122	8.2	7.3
India	31	231	0.0	0.1
Israel	336	1 098	0.3	0.7
Japan	21 144	33 721	22.0	20.3
Mexico	36	120	0.0	0.1
Russian Federation	–	338	–	0.2
South Africa	115	132	0.1	0.1
United Kingdom	2 969	4 622	3.1	2.8
United States of America	51 703	89 565	53.7	54.0

* USSR in 1991 = 179 patents

Source: USPTO data compiled by Canadian Science and Innovation Indicators Consortium (CSIIC).

Table 4
REGIONAL ORIGINS OF PATENTS AT THE EPO, USPTO AND JPO, 2000

	Total 1991	Total 2000	% world 1991	% world 2000
World	**29 901**	**43 625**	**100.0**	**100.0**
Developed countries	27 788	40 210	92.9	92.2
Developing countries	2 113	3 415	7.1	7.8
Less-developed countries	0	0	0.0	0.0
Americas	**12 301**	**17 696**	**41.1**	**40.6**
North America	10 492	15 504	35.1	35.5
Latin America and Caribbean	1 809	2 192	6.0	5.0
Europe	**8 228**	**12 599**	**27.5**	**28.9**
European Union	7 382	11 642	24.7	26.7
Comm. of Ind. States in Europe	43	78	0.1	0.2
Central, Eastern & Other Europe	803	879	2.7	2.0
Africa	**18**	**28**	**0.1**	**0.1**
Sub-Saharan countries	17	28	0.1	0.1
Arab States Africa	1	0	0.0	0.0
Asia	**9 179**	**12 945**	**30.7**	**29.7**
Comm. of Ind. States in Asia	0	0	0.0	0.0
Newly Indust. in Asia	150	698	0.5	1.6
Arab States in Asia	1	3	0.0	0.0
Other in Asia	8	6	0.0	0.0
Oceania	**175**	**357**	**0.6**	**0.8**
Other groupings				
Arab States All	2	3	0.0	0.0
Comm. of Ind. States All	43	78	0.1	0.2
OECD	27 822	40 610	93.0	93.1
Selected countries				
Argentina	5	11	0.0	0.0
Brazil	6	34	0.0	0.1
China	12	93	0.0	0.2
Egypt	1	0	0.0	0.0
France	161	489	0.5	1.1
Germany	3 676	5 777	12.3	13.2
India	9	46	0.0	0.1
Israel	104	342	0.3	0.8
Japan	8 895	11 757	29.7	27.0
Mexico	6	15	0.0	0.0
Russian Federation	37	76	0.1	0.2
South Africa	17	28	0.1	0.1
United Kingdom	1 250	1 794	4.2	4.1
United States of America	10 217	14 985	34.2	34.3

Notes: UNESCO Institute for Statistics estimations of patents applied for at the EPO, USPTO and JPO.

Source: OECD, Patent Database, September/October 2004.

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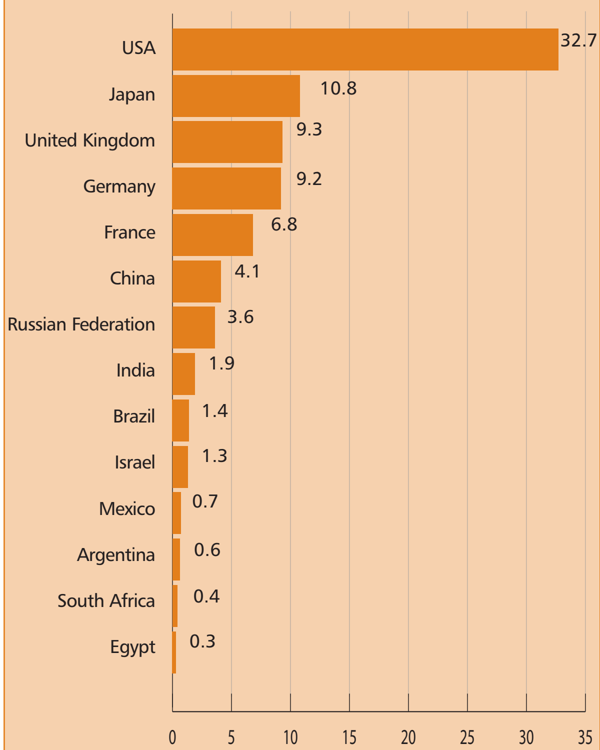
business environment is still in its infancy or having a hard time surviving in many developing countries. It takes more than time to create an environment conducive to patents, but time is an important factor. It is for this reason that we cannot yet see China's prowess in GERD reflected in a visible share of the USPTO and EPO patent data: it accounted for 0.2% of USPTO patents granted in 2001, and 0.3% of patent applications to the EPO in 2000. The same goes for Turkey, which has seen a sharp increase in publications but the rise is still to come in patents. The Newly Industrialized Asian economies, with their longer tradition, are now clearly visible, with 5.9% of patents granted by the USPTO and 1.5% of patent applications to

Figure 2
WORLD SHARES OF SCIENTIFIC PUBLICATIONS, 2001
Selected countries (%)



Source: see Table 5.

Table 5
WORLD SHARES OF SCIENTIFIC PUBLICATIONS, 1991 AND 2001

	Total		% world	
	1991	2001	1991	2001
World	**455 315**	**598 447**	**100.0**	**100.0**
Developed countries	420 089	524 306	92.3	87.6
Developing countries	46 694	103 757	10.3	17.3
Less developed countries	979	1 526	0.2	0.3
Americas	**206 772**	**232 856**	**45.4**	**38.9**
North America	199 943	216 652	43.9	36.2
Latin America and Caribbean	8 227	19 960	1.8	3.3
Europe	**187 683**	**276 152**	**41.2**	**46.1**
European Union	164 470	241 071	36.1	40.3
Comm. of Ind. States in Europe	12 026	25 018	2.6	4.2
Central, Eastern & Other Europe	15 224	25 184	3.3	4.2
Africa	**7 058**	**8 608**	**1.6**	**1.4**
Sub-Saharan countries	4 636	5 105	1.0	0.9
Arab States Africa	2 431	3 536	0.5	0.6
Asia	**73 542**	**134 870**	**16.2**	**22.5**
Comm. of Ind. States in Asia	813	1 047	0.2	0.2
Newly Indust. in Asia	6 521	24 253	1.4	4.1
Arab States in Asia	1 470	2 012	0.3	0.3
Other in Asia	1 331	3 315	0.3	0.6
Oceania	**13 126**	**19 655**	**2.9**	**3.3**
Other groupings				
Arab States All	3 838	5 416	0.8	0.9
Comm. of Ind. States all	12 706	25 902	2.8	4.3
OECD	408 354	519 951	89.7	86.9
Selected countries				
Argentina	1 719	3 756	0.4	0.6
Brazil	3 105	8 564	0.7	1.4
China	6 340	24 367	1.4	4.1
Egypt	1 651	1 830	0.4	0.3
France	27 335	40 485	6.0	6.8
Germany	37 112	55 212	8.2	9.2
India	9 848	11 620	2.2	1.9
Israel	5 409	7 744	1.2	1.3
Japan	42 653	64 655	9.4	10.8
Mexico	1 307	4 049	0.3	0.7
Russian Federation	9 718	21 315	2.1	3.6
South Africa	2 618	2 657	0.6	0.4
United Kingdom	40 789	55 363	9.0	9.3
United States of America	179 615	195 660	39.4	32.7

Note: The sum of the numbers, and percentages, for the various regions exceeds the total number, or 100%, because papers with multiple authors from different regions contribute fully to each of these regions.

Source: ISI, data compiled by Canadian Science and Innovation Indicators Consortium (CSIIC).

Table 6
WORLD SHARES OF SCIENTIFIC PUBLICATIONS, 1991 AND 2001
By field

	Biology		Biomedical research		Chemistry		Clinical medicine		Earth and space	
	1991	2001	1991	2001	1991	2001	1991	2001	1991	2001
World	**37 755**	**45 482**	**76 337**	**93 557**	**58 580**	**77 351**	**150 788**	**190 400**	**22 536**	**33 376**
Developed countries	34 202	40 103	72 545	85 646	51 723	62 894	142 361	173 692	20 860	30 415
Developing countries	4 953	8 537	5 343	11 596	8 231	18 177	10 784	22 129	2 661	5 478
Less-developed countries	216	350	109	213	57	59	488	694	43	91
Americas	**18 844**	**18 857**	**38 432**	**44 568**	**18 404**	**20 456**	**71 801**	**81 593**	**12 287**	**16 074**
North America	17 951	16 751	37 303	42 262	17 602	18 247	69 972	77 710	11 822	15 064
Latin America and Caribbean	1 155	2 747	1 339	2 865	877	2 504	2 207	4 742	626	1 460
Europe	**12 135**	**19 101**	**31 222**	**40 958**	**27 917**	**37 855**	**62 126**	**85 483**	**9 103**	**16 493**
European Union	11 109	17 007	27 485	37 020	22 649	30 574	57 326	78 919	7 937	14 368
Comm. of Ind. States in Europe	341	1 101	1 820	2 339	3 535	5 693	1 043	925	645	1 726
Central, Eastern & Other Europe	859	1 669	2 569	3 440	2 240	3 401	4 829	8 259	779	1 615
Africa	**1 257**	**1 445**	**788**	**973**	**1 278**	**1 290**	**2 227**	**2 456**	**453**	**597**
Sub-Saharan countries	1 008	1 153	644	774	416	341	1 793	1 858	325	411
Arab States Africa	249	284	146	198	862	974	441	592	128	184
Asia	**5 464**	**8 012**	**9 943**	**16 773**	**13 134**	**23 190**	**18 309**	**32 799**	**2 491**	**5 073**
Comm. of Ind. States in Asia	24	33	130	46	241	293	71	48	36	68
Newly Indust. in Asia	539	1 372	617	2 558	1 211	3 808	1 460	4 915	192	865
Arab States in Asia	136	174	104	168	211	232	543	712	108	114
Other in Asia	249	454	134	310	188	626	402	942	60	164
Oceania	**2 590**	**3 309**	**2 063**	**2 919**	**1 093**	**1 537**	**4 428**	**6 616**	**1 095**	**1 914**
Other groupings										
Arab States All	379	447	248	358	1 059	1 151	971	1 285	229	295
Comm. of Ind. States All	360	1 128	1 919	2 379	3 738	5 958	1 099	970	672	1 774
OECD	33 989	40 037	70 539	85 392	48 067	59 929	141 579	176 816	20 308	29 890
Selected countries										
Argentina	221	569	257	572	253	475	430	932	96	246
Brazil	304	954	585	1 255	263	1 123	806	1 985	204	474
China	294	982	307	1 984	1 169	5 915	789	2 897	329	1 190
Egypt	165	164	98	88	657	573	251	349	92	70
France	1 520	2 341	4 845	6 515	4 241	5 145	7 861	10 751	1 523	2 968
Germany	2 300	3 032	5 957	8 342	5 855	7 388	10 642	16 520	1 725	3 299
India	925	841	1 110	1 522	2 587	2 788	1 380	1 789	607	613
Israel	561	593	902	1 163	386	617	1 870	2 527	223	368
Japan	2 866	3 929	6 756	9 353	7 249	9 686	11 959	19 244	994	1 968
Mexico	209	639	198	471	122	392	287	821	130	416
Russian Federation	300	1 000	1 520	2 195	2 848	4 903	891	800	579	1 602
South Africa	505	490	402	442	290	241	859	742	220	285
United Kingdom	3 041	4 113	7 276	9 399	4 263	5 366	16 142	19 994	2 226	4 131
United States of America	14 880	14 045	34 018	38 955	15 702	16 233	63 794	70 796	10 278	13 332

Note: The sum of the numbers, and percentages, for the various regions exceeds the total number, or 100%, because papers with multiple authors from different regions contribute fully to each of these regions

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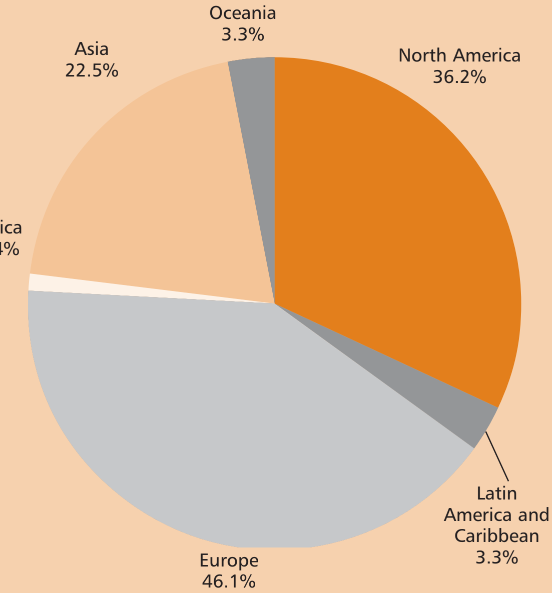
Engineering and technology 1991	2001	Mathematics 1991	2001	Physics 1991	2001	Unknown 1991	2001
35 340	**55 858**	**8 162**	**14 278**	**65 507**	**88 004**	**310**	**142**
31 436	44 723	7 507	12 445	59 148	74 253	307	135
5 044	14 639	1 047	3 029	8 627	20 161	4	12
33	55	3	4	30	61	–	0
16 360	**18 832**	**4 369**	**5 727**	**26 155**	**26 689**	**120**	**60**
16 050	17 635	4 223	5 304	24 901	23 620	119	59
378	1 379	188	508	1 456	3 754	1	1
11 913	**22 611**	**3 384**	**7 466**	**29 696**	**46 108**	**187**	**77**
10 347	19 267	3 032	6 633	24 520	37 217	65	68
768	2 435	178	706	3 696	10 078	–	16
967	2 092	220	533	2 628	4 172	133	3
437	**693**	**58**	**197**	**560**	**951**	**–**	**4**
180	217	30	83	240	265	–	2
257	485	28	116	320	703	–	2
8 406	**18 852**	**1 209**	**2 999**	**14 578**	**27 156**	**8**	**17**
44	53	27	38	240	466	–	0
1 344	5 207	122	588	1 036	4 935	–	4
220	372	25	51	123	188	–	1
90	338	31	84	176	398	1	0
643	**1 357**	**220**	**448**	**992**	**1 554**	**2**	**0**
466	847	53	164	433	865	–	2
802	2 481	203	743	3 913	10 453	–	16
30 822	45 053	7 312	12 160	55 546	70 543	192	130
89	204	26	81	347	677	–	0
155	737	80	240	707	1 795	1	1
936	4 300	272	1 016	2 244	6 083	–	0
196	268	11	21	181	295	–	2
1 512	3 212	503	1 695	5 325	7 841	5	16
2 852	4 303	677	1 391	7 092	10 926	12	11
1 165	1 503	127	198	1 947	2 365	–	1
390	675	193	382	882	1 418	2	1
4 312	7 122	426	785	8 086	12 558	5	9
62	274	39	81	260	956	–	0
580	1 816	143	591	2 857	8 393	–	15
121	185	25	65	196	207	–	0
2 673	4 479	678	1 093	4 457	6 779	33	9
14 151	15 622	3 830	4 819	22 853	21 806	109	52

Source: ISI data compiled by Canadian Science and Innovation Indicators Consortium (CSIIC).

Figure 3
WORLD SHARES OF SCIENTIFIC PUBLICATIONS, 2001
By continent



Note: The sum of the percentages, for the various regions exceeds 100%, because papers with multiple authors from different regions contribute fully to each of these regions.

Source: see Table 5.

the EPO. With the notable exception of North America, Europe, Japan and Israel, the rest of the world is virtually absent, illustrating the stark odds to be overcome. The Russian case deserves special mention. The Russian Federation has an extremely small number of international patents to its credit, an image only partly nuanced by the large number of domestic patents granted; this is more a reflection of the once (and enduring?) dominant role of state industry than of a globally competing industry (see the chapter on the Russian Federation).

Much more difficult to interpret are indicators of international trade in high-tech products (Table 7). One reason is that usually broad sectors as a whole are redefined as high-, low- or medium-tech sectors, even though there are often large differences among sub-sectors. Another reason is the dissection of the manufacturing or production process. Drawings,

Table 7
INTERNATIONAL TRADE IN HIGH-TECH PRODUCTS, 2002
In US$ million

	Aerospace products				Armaments				Chemistry (less pharmaceuticals)			
	Import	% World	Export*	% World	Import	% World	Export*	% World	Import	% World	Export*	% World
World	**99 112**	**100.0**	**112 228**	**100.0**	**5 199**	**100.0**	**5 887**	**100.0**	**25 400**	**100.0**	**22 941**	**100.0**
Developed countries	83 032	83.8	98 713	88.0	3 766	72.4	5 071	86.1	19 424	76.5	16 619	72.4
Developing countries	16 038	16.2	5 212	4.6	1 411	27.1	433	7.3	5 858	23.1	5 273	23.0
Less-developed countries	42	0.0	8 304	7.4	23	0.4	384	6.5	118	0.5	1 049	4.6
Americas	**29 116**	**29.4**	**43 300**	**38.6**	**1 836**	**35.3**	**2 922**	**49.6**	**6 768**	**26.6**	**5 005**	**21.8**
North America	26 872	27.1	39 622	35.3	1 678	32.3	2 690	45.7	4 616	18.2	3 899	17.0
Latin America and the Caribbean	2 244	2.3	3 678	3.3	157	3.0	232	3.9	2 152	8.5	1 107	4.8
Europe	**48 500**	**48.9**	**57 674**	**51.4**	**2 065**	**39.7**	**2 247**	**38.2**	**12 340**	**48.6**	**11 871**	**51.7**
European Union	46 162	46.6	54 402	48.5	1 555	29.9	1 791	30.4	10 682	42.1	10 841	47.3
Comm. of Ind. States in Europe	345	0.3	1 076	1.0	5	0.1	52	0.9	876	3.4	270	1.2
Central, Eastern & Other Europe	1 965	2.0	2 156	1.9	497	9.6	393	6.7	497	2.0	737	3.2
Africa	**1 607**	**1.6**	**8 415**	**7.5**	**63**	**1.2**	**401**	**6.8**	**612**	**2.4**	**1 332**	**5.8**
Sub-Saharan countries	1 095	1.1	8 400	7.5	49	0.9	401	6.8	410	1.6	1 327	5.8
Arab States Africa	511	0.5	14	0.0	14	0.3	0	0.0	202	0.8	4	0.0
Asia	**16 951**	**17.1**	**2 112**	**1.9**	**1 006**	**19.4**	**288**	**4.9**	**5 297**	**20.9**	**4 527**	**19.7**
Comm. of Ind. States in Asia	7	0.0	3	0.0	0	0.0	0	0.0	10	0.0	1	0.0
Newly Indust. in Asia	5 844	5.9	1 190	1.1	290	5.6	87	1.5	1 330	5.2	2 680	11.7
Arab States in Asia	77	0.1	1	0.0	301	5.8	0	0.0	184	0.7	29	0.1
Other in Asia	1 065	1.1	23	0.0	191	3.7	41	0.7	746	2.9	524	2.3
Oceania	2 938	3.0	728	0.6	229	4.4	30	0.5	383	1.5	207	0.9
Other groupings												
Arab States All	588	0.6	16	0.0	315	6.1	1	0.0	386	1.5	34	0.1
Comm. of Ind. States All	352	0.4	1 079	1.0	5	0.1	52	0.9	885	3.5	271	1.2
OECD	83 349	84.1	98 854	88.1	4 187	80.5	5 130	87.1	19 297	76.0	16 950	73.9
Selected countries												
Argentina	189	0.2	83	0.1	2	0.0	7	0.1	169	0.7	207	0.9
Brazil	703	0.7	2 767	2.5	13	0.2	205	3.5	532	2.1	409	1.8
China	3 472	3.5	6	0.0	4	0.1	2	0.0	560	2.2	35	0.2
Egypt	0	0.0	0	0.0	1	0.0	0	0.0	41	0.2	1	0.0
France	7 007	7.1	18 235	16.2	87	1.7	252	4.3	2 421	9.5	2 887	12.6
Germany	11 208	11.3	16 837	15.0	101	1.9	216	3.7	1 573	6.2	2 551	11.1
India	648	0.7	3	0.0	3	0.1	2	0.0	108	0.4	345	1.5
Israel	555	0.6	14	0.0	0	0.0	0	0.0	92	0.4	217	0.9
Japan	5 284	5.3	872	0.8	217	4.2	155	2.6	2 267	8.9	695	3.0
Mexico	350	0.4	783	0.7	37	0.7	18	0.3	436	1.7	191	0.8
Russian Federation	311	0.3	888	0.8	5	0.1	52	0.9	650	2.6	220	1.0
South Africa	812	0.8	67	0.1	0	0.0	7	0.1	139	0.5	219	1.0
United Kingdom	15 013	15.1	11 112	9.9	577	11.1	601	10.2	1 267	5.0	1 967	8.6
United States of America	22 099	22.3	39 615	35.3	1 250	24.0	2 689	45.7	3 681	14.5	3 899	17.0

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Computers and office machines				Electrical machinery				Electronics-telecommunications			
Import	% World	Export*	% World	Import	% World	Export*	% World	Import	% World	Export*	% World
304 189	**100.0**	**269 052**	**100.0**	**33 161**	**100.0**	**29 372**	**100.0**	**472 106**	**100.0**	**421 235**	**100.0**
219 007	72.0	134 611	50.0	19 008	57.3	19 361	65.9	244 424	51.8	234 283	55.6
85 002	27.9	132 064	49.1	14 143	42.7	9 447	32.2	227 339	48.2	180 187	42.8
181	0.1	2 377	0.9	10	0.0	564	1.9	343	0.1	6 765	1.6
89 989	**29.6**	**35 688**	**13.3**	**7 147**	**21.6**	**5 411**	**18.4**	**110 750**	**23.5**	**65 248**	**15.5**
78 620	25.8	24 560	9.1	5 331	16.1	3 677	12.5	87 751	18.6	51 504	12.2
11 369	3.7	11 127	4.1	1 817	5.5	1 734	5.9	22 999	4.9	13 744	3.3
117 910	**38.8**	**86 323**	**32.1**	**11 380**	**34.3**	**10 085**	**34.3**	**131 204**	**27.8**	**134 657**	**32.0**
110 738	36.4	85 511	31.8	10 660	32.1	9 391	32.0	121 071	25.6	131 286	31.2
789	0.3	51	0.0	102	0.3	256	0.9	2 191	0.5	477	0.1
5 467	1.8	712	0.3	449	1.4	358	1.2	6 161	1.3	2 396	0.6
1 815	**0.6**	**3 379**	**1.3**	**218**	**0.7**	**718**	**2.4**	**3 789**	**0.8**	**7 779**	**1.8**
1 180	0.4	3 370	1.3	96	0.3	689	2.3	2 365	0.5	7 123	1.7
635	0.2	9	0.0	122	0.4	28	0.1	1 424	0.3	656	0.2
90 130	**29.6**	**142 928**	**53.1**	**14 084**	**42.5**	**13 010**	**44.3**	**222 018**	**47.0**	**212 808**	**50.5**
33	0.0	0	0.0	4	0.0	0	0.0	81	0.0	5	0.0
44 095	14.5	97 549	36.3	5 753	17.3	4 299	14.6	124 731	26.4	134 404	31.9
723	0.2	12	0.0	61	0.2	2	0.0	1 346	0.3	27	0.0
8 395	2.8	21 948	8.2	1 791	5.4	2 751	9.4	24 948	5.3	26 796	6.4
4 346	1.4	735	0.3	332	1.0	149	0.5	4 345	0.9	742	0.2
1 358	0.4	21	0.0	184	0.6	30	0.1	2 770	0.6	683	0.2
822	0.3	52	0.0	106	0.3	256	0.9	2 272	0.5	482	0.1
230 291	75.7	161 407	60.0	21 829	65.8	21 277	72.4	276 644	58.6	271 992	64.6
155	0.1	33	0.0	24	0.1	7	0.0	143	0.0	51	0.0
1 139	0.4	154	0.1	213	0.6	51	0.2	2 710	0.6	1 479	0.4
15 642	5.1	14	0.0	3 290	9.9	2	0.0	43 772	9.3	31	0.0
165	0.1	1	0.0	29	0.1	0	0.0	254	0.1	1	0.0
11 398	3.7	6 005	2.2	1 002	3.0	648	2.2	12 971	2.7	14 162	3.4
24 072	7.9	14 053	5.2	3 118	9.4	2 795	9.5	25 872	5.5	29 312	7.0
1 294	0.4	142	0.1	150	0.5	11	0.0	2 587	0.5	431	0.1
872	0.3	237	0.1	920	2.8	485	1.7	1 806	0.4	3 592	0.9
19 076	6.3	23 026	8.6	2 115	6.4	5 460	18.6	22 745	4.8	47 522	11.3
7 880	2.6	10 915	4.1	1 420	4.3	1 670	5.7	15 604	3.3	12 135	2.9
636	0.2	35	0.0	71	0.2	217	0.7	1 723	0.4	325	0.1
853	0.3	79	0.0	70	0.2	29	0.1	1 741	0.4	244	0.1
19 073	6.3	14 634	5.4	1 705	5.1	2 238	7.6	19 953	4.2	28 459	6.8
70 500	23.2	24 560	9.1	4 827	14.6	3 677	12.5	77 386	16.4	51 504	12.2

Table 7 (continued)

	Non-electrical machinery				Pharmaceuticals				Scientific instruments			
	Import	% World	Export*	% World	Import	% World	Export*	% World	Import	% World	Export*	% World
World	**23 241**	**100.0**	**25 256**	**100.0**	**51 756**	**100.0**	**50 102**	**100.0**	**102 976**	**100.0**	**97 804**	**100.0**
Developed countries	15 954	68.6	22 970	90.9	43 247	83.6	46 145	92.1	69 837	67.8	80 276	82.1
Developing countries	7 278	31.3	1 297	5.1	8 297	16.0	3 592	7.2	33 049	32.1	15 636	16.0
Less-developed countries	9	0.0	989	3.9	212	0.4	365	0.7	90	0.1	1 892	1.9
Americas	**6 189**	**26.6**	**6 544**	**25.9**	**11 476**	**22.2**	**7 888**	**15.7**	**28 805**	**28.0**	**25 813**	**26.4**
North America	4 606	19.8	6 157	24.4	8 654	16.7	7 173	14.3	23 858	23.2	23 018	23.5
Latin America and the Caribbean	1 583	6.8	387	1.5	2 822	5.5	716	1.4	4 947	4.8	2 795	2.9
Europe	**10 452**	**45.0**	**14 192**	**56.2**	**32 249**	**62.3**	**37 826**	**75.5**	**38 172**	**37.1**	**44 140**	**45.1**
European Union	8 860	38.1	11 699	46.3	25 722	49.7	29 866	59.6	34 113	33.1	39 081	40.0
Comm. of Ind. States in Europe	511	2.2	717	2.8	652	1.3	92	0.2	1 040	1.0	693	0.7
Central, Eastern & Other Europe	953	4.1	1 741	6.9	5 465	10.6	7 673	15.3	2 498	2.4	4 270	4.4
Africa	**280**	**1.2**	**997**	**3.9**	**1 012**	**2.0**	**422**	**0.8**	**1 032**	**1.0**	**2 061**	**2.1**
Sub-Saharan countries	91	0.4	996	3.9	451	0.9	405	0.8	589	0.6	1 985	2.0
Arab States Africa	189	0.8	1	0.0	561	1.1	17	0.0	443	0.4	75	0.1
Asia	**6 071**	**26.1**	**3 470**	**13.7**	**6 345**	**12.3**	**3 759**	**7.5**	**33 442**	**32.5**	**25 286**	**25.9**
Comm. of Ind. States in Asia	47	0.2	1	0.0	30	0.1	0	0.0	30	0.0	9	0.0
Newly Indust. in Asia	1 700	7.3	381	1.5	1 240	2.4	1 977	3.9	10 253	10.0	8 351	8.5
Arab States in Asia	489	2.1	1	0.0	779	1.5	37	0.1	694	0.7	17	0.0
Other in Asia	1 461	6.3	337	1.3	664	1.3	44	0.1	4 407	4.3	3 281	3.4
Oceania	**249**	**1.1**	**52**	**0.2**	**674**	**1.3**	**208**	**0.4**	**1 526**	**1.5**	**503**	**0.5**
Other groupings												
Arab States All	678	2.9	2	0.0	1 340	2.6	54	0.1	1 136	1.1	92	0.1
Comm. of Ind. States All	557	2.4	718	2.8	681	1.3	93	0.2	1 070	1.0	702	0.7
OECD	17 143	73.8	22686	89.8	44 002	85.0	46 249	92.3	74 922	72.8	82 755	84.6
Selected countries												
Argentina	71	0.3	13	0.1	193	0.4	138	0.3	109	0.1	43	0.0
Brazil	364	1.6	9	0.0	966	1.9	97	0.2	1 180	1.1	165	0.2
China	1 195	5.1	5	0.0	682	1.3	12	0.0	9 688	9.4	4	0.0
Egypt	2	0.0	0	0.0	194	0.4	9	0.0	83	0.1	0	0.0
France	1 226	5.3	1 624	6.4	4 024	7.8	4 115	8.2	4 781	4.6	4 635	4.7
Germany	2 100	9.0	3 158	12.5	4 896	9.5	4 048	8.1	7 431	7.2	13 952	14.3
India	119	0.5	20	0.1	405	0.8	658	1.3	812	0.8	266	0.3
Israel	75	0.3	129	0.5	104	0.2	38	0.1	676	0.7	701	0.7
Japan	986	4.2	2 597	10.3	2 442	4.7	991	2.0	6 882	6.7	12 657	12.9
Mexico	873	3.8	345	1.4	790	1.5	338	0.7	2 756	2.7	2 543	2.6
Russian Federation	254	1.1	605	2.4	479	0.9	74	0.1	830	0.8	478	0.5
South Africa	76	0.3	6	0.0	171	0.3	21	0.0	433	0.4	67	0.1
United Kingdom	2 108	9.1	2 228	8.8	2 959	5.7	3 893	7.8	5 793	5.6	6 300	6.4
United States of America	3 596	15.5	6 157	24.4	7 522	14.5	7 172	14.3	19 573	19.0	23 018	23.5

Notes:
* All export figures are minus re-exports. Armenia: Re-exports not subtracted.

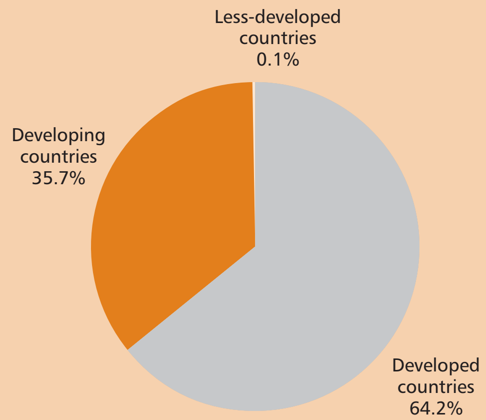
component parts and subsystems come from all over the world and make several voyages across the globe before reaching their final resting place where all will be assembled. Even then, this may differ from the site for packaging and distribution.

Moreover, volumes of trade depend very much on the size of the countries concerned. Even if we define country conglomerates in order to arrive at more equal sizes, we should then ideally subtract all 'inter-conglomerate' trade. In pharmaceuticals for example, the world's total

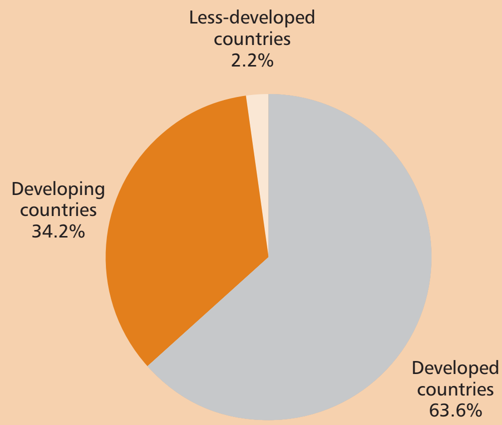
Import	% World	Total Export*	% World
1 117 139	**100.0**	**1 033 878**	**100.0**
717 698	64.2	658 048	63.6
398 414	35.7	353 141	34.2
1 027	0.1	22 689	2.2
292 076	**26.1**	**197 819**	**19.1**
241 986	21.7	162 299	15.7
50 090	4.5	35 520	3.4
404 270	**36.2**	**399 016**	**38.6**
369 563	33.1	373 868	36.2
6 510	0.6	3 685	0.4
23 953	2.1	20 437	2.0
10 428	**0.9**	**25 503**	**2.5**
6 327	0.6	24 696	2.4
4 101	0.4	806	0.1
395 345	**35.4**	**408 187**	**39.5**
242	0.0	19	0.0
195 235	17.5	250 919	24.3
4 653	0.4	126	0.0
43 669	3.9	55 743	5.4
15 021	**1.3**	**3 352**	**0.3**
8 754	0.8	933	0.1
6 752	0.6	3 704	0.4
771 663	69.1	727 300	70.3
1 055	0.1	583	0.1
7 821	0.7	5 334	0.5
78 304	7.0	111	0.0
768	0.1	13	0.0
44 918	4.0	52 563	5.1
80 370	7.2	86 922	8.4
6 126	0.5	1 879	0.2
5 101	0.5	5 414	0.5
62 016	5.6	93 976	9.1
30 146	2.7	28 937	2.8
4 960	0.4	2 894	0.3
4 296	0.4	740	0.1
68 448	6.1	71 432	6.9
210 433	18.8	162 291	15.7

Source: COMTRADE (2002). Methodology based on SICT Rev. 3, as proposed in OCDE/GD(97)216.

Percentage of world high-tech imports



Percentage of world high-tech exports (minus re-exports)



imports in 2002 amounted to almost US$ 52 billion, a considerable share of which were intra-European imports. However, total pharmaceuticals sales that same year amounted to US$ 400 billion. As a consequence, import and export statistics tell many stories which have to be disentangled to uncover the reality by breaking down figures for sectors and countries. High shares of high-tech exports do not therefore always correlate very well with technological capabilities. Using cheap labour in foreign-dominated factories with little technology transfer

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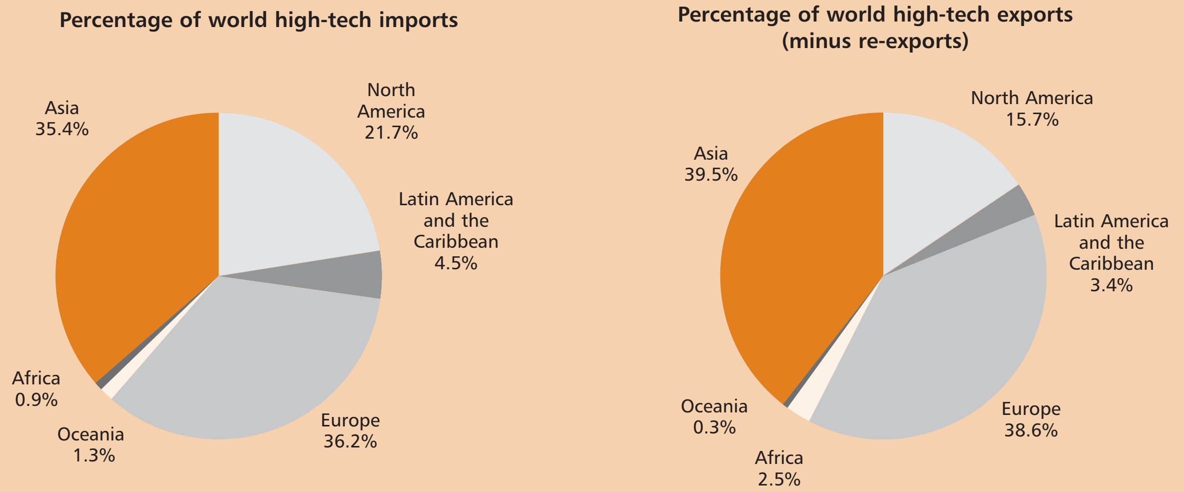
Figure 4
WORLD HIGH-TECH IMPORTS AND EXPORTS, 2002
By continent



Source: see Table 7.

may help with the statistics but less with development.

Considering data for the USA and the EU reveals that US exports are sometimes deceptively low but that is to be expected for most sectors in a large economy. By contrast, the EU data are deceptively high because of the large amount of intra-EU trade.

Carefully read, however, high-tech import and export statistics do show some interesting features. The prominent position of the Newly Industrialized Asian economies stands out, especially in computers and office machines, in electronics and telecommunications and to a lesser extent in electrical machinery, for example.

The observation that the emergence of China is not yet reflected in patent statistics is confirmed by its weak position so far in high-tech exports. At the same time, the dynamics are clearly visible: China now imports more scientific instruments, electronics and telecommunications products and electrical machinery than Japan.

A strong position in aerospace and military technology can be read into the large export shares for the USA. Similarly, the large export shares for scientific instruments and electrical machinery seem to be an indication of Japan's continuing strong position in high-quality manufacturing, the volume of which is even growing, according to recent statistics, in a trend that is swimming against the outsourcing tide.

INNOVATION: THE TRIPLE HELIX AS A NECESSARY CONDITION

Since gaining acceptance in policy circles in the mid-1970s, the word 'innovation' has gained ever-more prominence. Indeed, the proverbial alien visitor to our planet could easily come to the conclusion that life on Earth is all about innovation. It is the talk of the town all over the world. National or regional systems of innovation have become the standard term for describing the many activities, parties and arrangements which interact to underpin successful innovative economies and societies.

This dynamic is known as the 'Triple Helix', the way in which cooperation between companies, knowledge institutions and government bodies pushes the economy continually upwards, like Ralph Vaughan Williams's 'Lark ascending'.

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Or, in the mesmerizing words of the children's choir of a Kampala primary school gracing with its presence the National Meeting on Science, Technology and Innovation in Uganda in March 2005, 'Innovation is an invitation to elevation'.

Simultaneously, the so-called linear model of innovation – basic research providing the input to applied research, which in turn underpins technologies resulting in innovation – has been relegated to the rubbish heap of history.

It is indeed of great importance to develop systematically the interaction between universities, research institutes, enterprises, local and regional governments, chambers of commerce, schools, banks, venture capital funds or private investors. This will result in networks or systems of innovation and clusters of economic activity, the very fabric out of which innovative economies and societies are woven; for even in a globalizing world where ICT is driving global technology flows, local, regional and national knowledge networks play a crucial role in shaping innovative success and social progress.

Yet, we must not confuse the roles played by the various parties, nor overlook the different natures of science, technology and innovation. The underlying processes have been described conveniently as three interlinked cycles. The first describes the development of science; the second, the development of technologies and problem-solving, and the third, the development of innovations. Here, an innovation in its most rudimentary form is simply a new idea that has proven successful as a product on the market, as a therapy applied in hospitals, as a new policy arrangement adopted by governments worldwide and so on.

The three cycles overlap and there are multiple interactions at various times between the persons and organizations involved in any one of these cycles. This said, the persons and organizations involved usually differ from cycle to cycle. This has to do with different personal capabilities, mentalities and aspirations, different reward systems or varying institutional missions.

The private sector plays a crucial role in both the innovation cycle and the technology cycle, but much less so in the science cycle. That is one reason for the private sector to strengthen links with universities. Universities and institutes for basic science dominate the science cycle, but for them too, closer links with industry or public sector stakeholders have become essential.

The new relations among the components of the Triple Helix are certainly still taking shape but clear patterns are emerging. Let us first concentrate on the dominance of private sector funding of GERD, followed by the new mechanisms for interaction. We shall then look at the new equilibrium on key issues like intellectual property before studying the implications for government's role.

Industry increasingly dominates R&D funding

The importance of the private sector's role is reflected in the fact that it finances the lion's share of national R&D in the developed nations. For every country or region aspiring to play a role in today's emerging knowledge societies, this is now an ineluctable challenge that goes beyond simply making funds available for R&D from the public purse. The private sector must play a leading role and this role can no longer be stimulated artificially by massive government subsidies. The various chapters that follow in the present *UNESCO Science Report* provide ample, remarkable evidence of this.

In the USA, industry has come to dominate the performance of R&D. A ten-fold increase in real terms between 1953 and 2000 has brought the amount of R&D performed by industry from US$ 3.6 billion in 1953 (or US$ 18.9 billion in 1996 prices) to US$ 199.6 billion in 2000 (equivalent to US$ 186.7 billion in 1996 prices).

Moreover, whereas government subsidies accounted for 40% of industrial R&D in the USA in 1953, these had dropped back to just 10% by 2000 (Table 2 in the chapter on the USA). Industry funded 66% and performed 72% of R&D in the USA in 2000.

The same goes for other large OECD countries. In Japan, the UK, Germany and France, for example, industry performed over 63% of all R&D and funded between 54% (France) and 69% (Japan) of it. The UK seems to be the odd one out, with industry funding just 46% of all R&D. The explanation for this anomaly is to be found in the 18% financed from abroad, to a large extent by foreign companies.

It is true however that the average for the 15-Member EU (56% in 2001) is much lower than the figures for either the USA or Japan. This is now the cause of greatest concern in the EU and is widely interpreted as a sign of a lack of vitality and of perceived opportunities. In 2002, the EU vowed to devote 3% of GDP to R&D by 2010, two-thirds of which is to come from private industry. This is logical, since nowhere in the world does R&D funded by the public purse account for more than 1% of GDP. However, in the EU, industry contributes just 1% to the average expenditure for Member countries of 1.81% of GDP. This places the onus on industry to increase its share of spending on R&D. This is the model expounded by countries that already more than meet the EU target, such as Sweden or Finland or, if we look beyond the EU, Switzerland.

In this respect, it is interesting to note that, in each of Turkey, Bulgaria and Romania, industry contributes more than 50% of GERD.

Apart from Japan, just three countries or territories in Asia devote more than 2% of GDP to R&D: Singapore, the Republic of Korea and Taiwan of China. Industry contributes 50% in Singapore, 63% in Taiwan of China and 74% in Korea (OECD data for 2003 or last available year). In China, state-owned and private industry together perform 61% of R&D.

Industry performs just 23% of R&D in India. Whether or not industry manages to develop this role in the coming years will be decisive for India's chances of raising GERD from just over 1% to the declared goal of 2% of GDP.

The private sector's performance of R&D in India can be compared with that for Latin American giants Brazil (33%) and Mexico (30%); the estimates for other Latin American countries are however much lower.

At the other end of the spectrum, we have Africa, where industry plays only a very minor role in all but South Africa. The same is true for the Arab states in Asia.

So far, we have covered industry's share of national GERD. What about industry's role in taking over partial funding of university research to compensate, as some would have it, for its reduced emphasis on carrying out basic research itself? There is no room for optimism here. It will not be companies that fund the lion's share of academic research. The remarkable fact is that 60% of all university research in the USA is funded by the federal government, largely through five major agencies (see the chapter on the USA). A further 6–7% takes the form of industrial contracts, an equal amount is made up of state contributions and the remainder is funded from the universities' own income (which may of course include donations from companies, or more generally from the business community). This is remarkable because it runs counter to the cherished beliefs and hopes of many cash-strapped governments or eager university managers.

From isolation to interaction

Across the world, companies have gradually but markedly reduced their investments in the development of science. Their own laboratories are rarely the scientific strongholds they once were, as for example in the heyday of Bell Labs in the USA. Bell Labs invented the first transistors (between 1947 and 1952) and can count 11 Nobel laureates among past employees. Today, more than 90% of the scientists and engineers at Bell Labs focus on the needs of service providers, with the company maintaining only a small long-term research programme exploring wireless and optical networking, the Internet, multimedia communications, physics and mathematics.

This illustrates a second aspect: company labs are less and less closed shops. They must concentrate on core competences but at the same time keep track of an ever-wider spectrum of potentially relevant fields. A field such as bionanoelectronics exemplifies the interwovenness of scientific developments, and hence the need to cast one's net widely. Moreover, companies are looking for ways of being involved in generating value from knowledge they have developed outside their core business, without taking the lead themselves.

In finding solutions, companies have come to accept that, even in a globalizing world, proximity effects – being able to interact with companies, universities and institutes nearby – have lost nothing of their importance, as economists have

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established beyond a doubt. Companies are therefore engaging in an ever-larger number of alliances with competitors and suppliers in pre-competitive research or with companies from different market niches to open up new market segments at the interface of their own specialization.

Companies are also engaging in a wide range of relations with academia, for the private sector's smaller role in the development of science does not mean it no longer values science or links with universities. Quite the opposite is true. Companies consider science to be relevant, hold universities in high esteem for what they do best – education and frontier research – and want to build an intensive relationship with them.

Some companies are creating 'open campuses', an open space around their research laboratories to which they invite not only other R&D companies but also public research institutes and teams with whom interaction is expected to lead to further innovation. One example is the High Tech Campus Eindhoven in the Netherlands with the Philips Research Laboratory as a core.

Regional clusters are emerging within countries. The forerunner of these is Route 128 in the Boston area of the USA. More familiar may now be Silicon Valley, the established example from the same country. Later manifestations of these regional clusters are the city of Grenoble in southern France and the Bay Area around San Francisco in the USA.

In the present report, we can read about the ambitious decision by the Japanese to reform policies in order to accommodate these new conditions: the creation of Technopolises and regional clusters, of Technology Licensing Offices at universities and the ambition to establish 1 100 start-up companies within three years. India's three biotechnology clusters (Hyderabad, Bangalore and Delhi) are another example.

All these developments demonstrate the on-going validity of the arguments published in what remains, six years on, the most authoritative survey of the importance of basic academic research in the science cycle, *The Economic Benefits of Publicly Funded Basic Research: A Critical Review* by Salter and Martin (1999). Basic academic research is a source of technological opportunity; a source of new interactions, networks, technological options and hence of broadening technological diversity; and a source of skills to translate knowledge into practice, enhance the ability to solve complex technical problems and an entry ticket to the world's stock of knowledge.

Issues of principle in university–industry cooperation

The stronger links between companies, universities and research institutes have brought centre-stage a number of crucial issues touching upon the very essence of public sector responsibilities. These issues have arisen in part because of a new mutual positioning of firms and universities. Whereas the famous industrial research laboratories of the past were in a sense part of academia, the question now is whether academia has perhaps become too much a department of industry. The quest for patentable research results or for income from clinical trials, for example, has led many an individual faculty member – and entire university departments on campuses across the world – into a grey area where values such as independence, integrity, collaboration, openness and the public availability of results acquired by public money are put at risk.

One should probably argue that the debates emerging around these issues demonstrate that academia, industry and public authorities are trying to establish a new equilibrium where, on the one hand, those values proper to academic activities are safeguarded and, on the other hand, the value of the results of research (which is no longer solely an intellectual or cultural value but also an economic or a societal value) is recognized more explicitly.

There are many strands to these attempts to establish a new equilibrium. One relates to the role of universities. Whereas, in building up S&T capacities in a country, it is difficult to avoid shorter-term application-driven research, there is little doubt that, in mature systems, this should be left to specialized institutes or industry. Another strand deals with code-of-conduct issues surrounding, for example, the faculty member doubling as an entrepreneur.

Much wider issues relate to the global patent system. Ever more parties recognize that the current patent system and the arrangements related to the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) cannot adequately and fairly cope with issues such as the patentability of genes and natural resources. India's struggle to change the rules of the patent regulations (see the chapter on South Asia) illustrates the case for this.

However, we are also witnessing a much richer range of approaches to making available affordable solutions for infectious diseases that plague the developing world. HIV/AIDS strategies are one example but so are new public–private arrangements such as the one between the University of California at Berkeley (USA), OneWorld Health and the Melissa and Bill Gates Foundation. This trio is cooperating to produce a genetically engineered version of one of the most effective anti-malaria drugs, as reported by Bennett Davies in *The Scientist* in 2005. Here, royalty-free licences from a university, a non-profit drug development company and a charity are the ingredients of a new combination.

On a similar note, we all recall the controversy surrounding the human genome project a few years ago, when there was talk of commercializing the project to sequence the human genome. At the crucial juncture, the Wellcome Trust, a UK charity, teamed up with the US government. The Wellcome Trust increased massively its own investment in the project so that its own Sanger Institute could decode one-third of the 3 billion letters that make up 'the code of life'. Today, the completed sequences are freely available to the world's scientific community. While recognizing the important contribution made by the private consortium involved in sequencing the human genome, almost everyone heaved a sigh of relief when all the information on the human genome gained through the project was made available to the public. This near-miss sends a clear signal that the world needs to set limits to what can be done by private companies without guarantees that the results will be made freely available and usable.

Changing roles for government

The dominant role of private industry's contribution to GERD in all major knowledge economies makes it essential for governments to establish an environment for private industry that is conducive to investment in technology and development. That is why it is so important for governments to enhance the transparency of markets, establish solid intellectual property protection regimes and create stability and financial markets in which trust and openness, rather than corruption and clientelism, are the rule. Of course governments should continue to invest in basic science, infrastructure for research and high-quality education, however the latter may be financed. That is not for this introduction to expand upon.

Where such strong emphasis is placed on encouraging private companies to lead a country's R&D effort, it does however raise an interesting question: where does that leave the government's industrial policies? The answers are complex. In the future, countries will still go through a natural succession of industrial stages, driven by a combination of natural endowments and more general comparative advantages. However, the ubiquitous nature of ICT provides opportunities nowadays which cut across this natural sequence by enabling countries to 'leapfrog'. Globalization and the increasing openness of the world's trade regime, coupled with the consequent need for governments to provide flexible economic conditions, will make it much more difficult in the future to maintain such industrial policies, except in small countries like Singapore that happen to be at the crossroads of global trade or financial flows, or large countries like the USA which wish to maintain their ascendancy over the world when it comes to the space and defence industries.

Figure 7 in the chapter on Japan showing the scientific profiles of Japan, the USA and the EU ('the triad') is most enlightening in this regard. It reveals Japan's focus on physics and materials science, and the American leaning towards the earth and space sciences. The most interesting aspect of these scientific profiles is however the strong emphasis in the USA on medical and life sciences, as opposed to almost a disregard for the physical and material sciences and chemistry. This illustrates the importance of creating flexible conditions and strong incentive systems to develop emerging fields, in this case the medical and life sciences.

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Equally illustrative of the ubiquitous nature and potential of ICT is an observation that emanates from the chapter on the USA. There, it is mentioned that the R&D intensity of service industries in the USA is probably higher than in manufacturing, though it is much more difficult to pinpoint the sources of innovation for service industries. It does, however, underscore, the need for closely knit networked societies because interactions are crucial. The Triple Helix has become an essential condition.

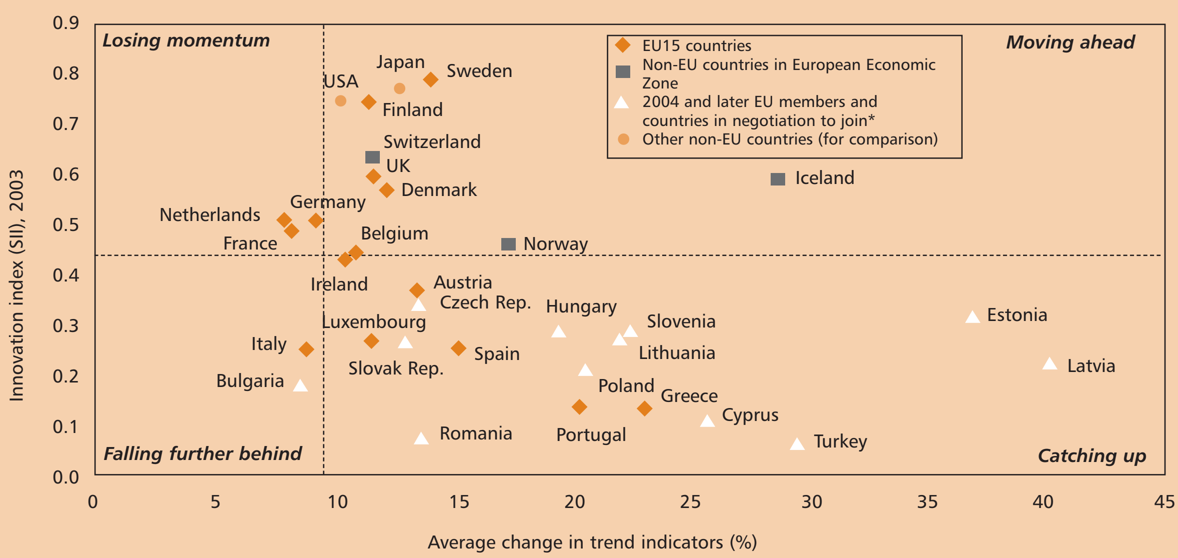
Measuring innovation

As innovation is at the heart of the Triple Helix, we are increasingly seeing attempts to capture not just input to S&T and the output of research but innovation itself, as the mechanism through which S&T 'delivers'. This desire to measure innovation can be seen, for example, in the EU, which nowadays uses an innovation index (SII). This index is composed of various indicators for measuring human resources (ranging from science and engineering graduates and investment in lifelong learning to employment in high-tech sectors); knowledge creation (such as R&D expenditure and patents); transmission and application of knowledge (such as the number of innovating small and medium-sized enterprises); and innovation finances, output and markets (such as venture capital availability and the share of high-tech in manufacturing industry).

A dynamic picture of where countries stand in terms of innovation emerges if we add the average annual change in each of these indicators over the past three years. This gives us the trend. Figure 5 illustrates the position of the 25 Members of the EU and of some other countries, among them the USA and Japan.

While it is clear that it does not yet make much sense to rank most countries from other parts of the world along these lines, they too should keep in mind that, in the longer run, closing on more developed knowledge-based societies requires that they pick up on development paths expressed in this type of graph.

Figure 5
TREND IN INNOVATION IN THE EUROPEAN UNION (25), 2000–03
Non-EU members are given for comparison



* Excludes Malta for which data are not available.

Source: http://trendchart.cordis.lu/scoreboard2003/index.html

Institutional issues with a focus on universities

A knowledge society requires a different institutional set-up from traditional societies and the industrial societies of the past 50 years in that the private sector will play an important role in the former. That does not mean however that the role of education and research institutions, be they public or private, is diminishing. Nor does it imply a dwindling role for governments.

The importance of a national vision

In developed countries and developing countries alike, governments need to have a clear, longer-term vision of the role of the various components – private companies, universities, government institutes, but also supportive mechanisms for technology transfer, or quality and safety control – of a science, technology and innovation system. Governments also need to have a clear idea of what needs to be done to stimulate the growth and interaction of these stakeholders.

Let us take one lesser-known example, that of Romania. Strongly motivated by its imminent membership of the EU in 2007, Romania has formulated six clear strategic goals, ranging from increasing GERD and stimulating enterprise R&D to institutional reforms (see the chapter on South-East Europe). In developing countries, there are three dangers that are hard to avoid without clear strategic goals. In the description of 'Median Africa', the chapter on Africa depicts the dangers of a market-oriented system. This is not a market formed by innovative national companies but rather one where international donors, aid programmes or multinational companies create powerful incentives for researchers which cannot be matched by a national S&T system unable to provide careers, modern equipment, professional standards and a vision which places the country in control of its own development.

In many Arab countries, we are seeing another danger, as depicted in the chapter on the Arab region, namely a situation where the main input to technology comes through turnkey investments by large foreign companies and international engineering consultancies. There is no anchoring of the technology on which the productive sector rests in the S&T system of the country itself.

Even when a much more developed S&T system exists, as in Latin American countries, caution should be exercised before engaging in international collaboration. This should bring not merely technology transfer but also capacity-building. The government must have a vision of what institutional building is needed and mould any policies accordingly, including those governing international collaboration and international donor involvement.

Tensions in the university system

Many of the tensions surrounding the evolution of a strong S&T system in developing countries surface in the university system. Examples abound in the various chapters of this *UNESCO Science Report*.

In many developing countries, a combination of factors is at work. An explosion in the higher educational system is on-going or imminent almost everywhere. With output exceeding local needs, a pool of unemployed or underemployed qualified graduates is being created. Moreover, most graduates are in the fields of management or business training, the arts and humanities, or sometimes in theoretical sciences, with little emphasis on applied sciences. This overproduction results in a mass exodus of graduate students, leading to a significant 'brain drain'. A multitude of new, often private universities have sprung up, usually focusing on 'fashionable fields'.

Russia's 3 400 new private universities offer a cautionary tale of what can happen in non-developing countries also when a lack of policies and regulations prevails. With the exception of a few, often smaller private universities, quality standards are lacking and there are no career policies based on performance. Few incentives for collaboration, sharing of equipment and concentration exist. Unfortunately, even the best-qualified researchers will soon lose their edge if they work in isolation because they will fail to keep up with the advances of modern science. Clear government policies are essential to reverse

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a situation which is now only too commonplace. In the absence of any policy identifying how public and private universities could cooperate to form a thriving higher education sector, there is one oversized national public university and a great many sub-standard private ones.

Universities in a globalizing world

It is not only in developing countries that universities are coming under great pressure to adapt to a new environment. Globalization is making its presence felt, as are the new demands on teaching and research, such as the need to address interdisciplinarity.

Here, we shall focus on globalization. The attention being given in 2004 to the ranking of the world's universities by Shanghai's Jiao Tong University is probably the best illustration of globalization. This is both because the ranking does not come from a traditional western university or magazine and because it brings into the picture universities across Asia and Oceania. High-quality tertiary institutions underscore the prominent position that China, India and the Newly Industrialized Countries in Asia are gradually claiming in the production of S&T. No doubt, these institutions have also been instrumental in bringing these countries to prominence. The Indian Institutes of Technology (see the chapter on South Asia) are an interesting example, their students being among the most sought-after by top American universities. The mobility of students and staff will raise the stakes for universities all over the world. Unavoidably, universities which are still often tightly bound up with national regulations and funding schemes will have to become much more autonomous. This goes hand in hand with much more transparent accountability regimes towards funding sources and with accreditation schemes.

There is another inevitable task which universities often choose to ignore and that is the task of defining realistically what they want to be. They do not need to emulate the American system to be struck by reasons for its strength. One of these strengths is the differentiation in mission and quality. The countries of the EU – and non-Member European countries – are now all in the process of moving towards a homogeneous Bachelor–Master–PhD system. However, it is difficult to see how the European university system can be sustainable if the tradition is maintained of every university performing significant amounts of research, or even extending this activity to institutes for higher professional education. In the USA, out of 3 400 degree-granting tertiary institutions, only 127 are research universities granting doctorates. Germany alone counts about 120 universities all claiming their share of the research pie. Moreover, this is not counting the professional universities of the *Fachhochschule* and the universities devoted to the arts, the *Kunst- und Musikhochschulen*.

In the United Kingdom, the government favours concentrating research but the House of Commons has come up with a plan for regionalizing research. Germany and, more recently, France have come to realize that large organizations for basic research outside the university system may do wonderful work but that, for the country's vitality, much closer links need to be established with universities. The German government's recent attempt to create 'elite universities' has been largely thwarted and turned into a funding mechanism for excellence programmes. Similarly, it remains to be seen whether the Japanese Centre of Excellence Programme (see the chapter on Japan) will result in further differentiation and concentration.

However, differentiation is not the only aspect of higher education that distinguishes the US system from the European one. Until now in Europe, with the exception of the UK, social expectations tended to mean that a two- or three-year degree comparable to a Bachelor's was not perceived as being a genuine university degree. Interestingly, this was also the case among employers. That attitude is both unsustainable and unnecessary for the labour market and for the integration of citizens into a knowledge society. The jury is out on whether the EU's formal introduction of Bachelor's and Master's degrees in all countries of Europe in an attempt to create a homogeneous pan-European Higher Education Area by 2010 is capable of forcing the system into a new equilibrium.

An important contribution to a thriving university system, and one that helps to enhance quality, differentiation and concentration, comes from having one or more professional research councils providing grants on a meritorious basis. The various chapters show that this lesson is beginning to be assimilated. China, the Russian Federation, Japan, Mexico and South Africa have all created bodies allocating grants on the basis of merit. In many other countries where such schemes exist but have fallen victim to political interference and nepotism, there is a growing acceptance of the need for reform. Even in Europe, there seems to be agreement on the need for a European Research Council to strengthen Europe's science base. This Council would create a 'uniform attractive force' for the best scientists which would not be handicapped by the limitations inevitably existing in national systems, or in the target-oriented environment of the EU's Framework Programmes for R&D.

CONCLUSION

To sum up, we have discussed a number of important cross-cutting issues in this overview of the state of science in the world. We have seen how players are repositioning their science, technology and innovation systems to cope with new realities.

However, if we single out one particular issue, perhaps the gravest concern for policy makers in large parts of the world is the almost intractable problem of brain drain. If there is one incentive for governments to strengthen universities, shape an environment conducive to private enterprise, remove stifling rules and build an open society, it is brain drain. By creating attractive conditions for highly trained personnel, countries can incite their 'human capital' to stay home, or return, to contribute to the development of their country or region.

Science is becoming increasingly dependent on international collaboration. Nowadays, scientists can participate in virtual research with collaborators who may be in the next room or on the next continent. Even if researchers have come to appreciate the advantages of globalization – or precisely for that reason – governments can give them reasons to want to work from home.

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Peter Tindemans is Director of the Global Knowledge Strategies and Partnerships consultancy in the Netherlands. In this capacity, he works with governments, research organizations, companies and international bodies on science and innovation policy, in Lebanon, Bahrain, Mexico, Uganda and Nigeria, but also on regional innovation policies in the Netherlands, Germany and Belgium. Other assignments include international evaluation panels such as the World Bank's Millennium Science Initiative and chairing both the Dutch Met Office and a Task Force on a European strategy for long-term access to digital data and efforts to establish the world's leading European Neutron Spallation Source.

He was Rapporteur-General of the World Conference on Science (1999) co-organized by UNESCO and the International Council for Science and of a government conference on genetically modified food (2000) co-organized by the OECD and the United Kingdom. He has also been Coordinator (with Pierre Papon) of the Europolis project on S&T policies for Europe.

Within the Netherlands administration, he was responsible for research and science policy until 1999, his first major achievement being the coordination of a first major framework for the country's innovation policy in 1979.

Peter Tindemans chaired the OECD Megascience Forum (1992–99) and COSINE Policy Group (1987–91) for a pan-European computer networking infrastructure. As a member of the Eureka High-level Group until 1991, he was involved in the preparation of European Union Framework Programmes. A former member of the Governing Board of Euroscience, an NGO promoting science in Europe, he sits on the Steering Group of the Initiative for Science in Europe (ISE).

Peter Tindemans holds a PhD (1975) in theoretical physics from Leyden University in the Netherlands.

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