



## 5.12 Science and technology

	Scientists and engineers in R&D	Technicians in R&D	Science and engineering students	Scientific and technical journal articles	Expenditures for R&D	High-technology exports		Royalty and license fees		Patent applications filed <sup>a</sup>	
	per million people 1987-97 <sup>b</sup>	per million people 1987-97 <sup>b</sup>	% of total tertiary students 1987-97 <sup>b</sup>	1995	% of GNP 1987-97 <sup>b</sup>	\$ millions 1998	% of manufactured exports 1998	Receipts \$ millions 1998	Payments \$ millions 1998	Residents 1997	Non-residents 1997
Albania	..	..	19	..	..	1	1	..	..	..	26,005
Algeria	..	..	58	..	..	5	1	..	..	34	206
Angola	..	..	24	..	..	..	..	17	0	..	..
Argentina	660	147	28	1,581	0.38	491	5	8	422	824	5,035
Armenia	1,485	177	29	..	..	6	5	..	..	63	25,059
Australia	3,357	797	24	9,747	1.80	1,564	11	275	1,010	8,937	39,274
Austria	1,627	812	33	2,807	1.53	5,877	12	99	811	2,681	108,543
Azerbaijan	2,791	188	37	..	0.21	..	..	..	..	..	24,308
Bangladesh	52	33	47	..	0.03	3	0	0	5	70	156
Belarus	2,248	266	48	..	1.07	204	4	1	1	755	25,280
Belgium	2,272	2,201	41	3,996	1.60	11,115	8	645	1,099	1,687	84,958
Benin	176	54	18	..	0.00	..	..	..	0	..	..
Bolivia	172	154	30	..	0.50	15	8	0	5	17	106
Bosnia and Herzegovina	..	..	..	5	..	..	..	..	..	..	23,197
Botswana	..	..	37	..	..	..	..	0	9	1	92
Brazil	168	59	27	2,760	0.81	2,554	9	142	1,075	36	31,947
Bulgaria	1,747	967	27	779	0.57	111	4	..	..	400	27,600
Burkina Faso	17	16	18	..	0.19	..	..	..	..	..	..
Burundi	33	32	20	..	0.31	..	..	0	0	1	4
Cambodia	..	..	13	..	..	..	..	..	..	..	..
Cameroon	..	..	45	..	..	2	2	..	..	..	..
Canada	2,719	1,070	16	17,359	1.66	21,736	15	574	2,073	4,192	50,254
Central African Republic	56	32	30	..	..	0	0	..	..	..	..
Chad	..	..	14	..	..	..	..	..	..	..	..
Chile	445	233	42	700	0.68	92	4	91	56	189	1,771
China	454	200	43	6,200	0.66	23,308	15	63	420	12,786	48,596
Hong Kong, China	..	..	36	1,091	..	4,751	21	..	..	26	2,359
Colombia	..	..	28	..	..	303	9	1	54	87	1,172
Congo, Dem. Rep.	..	..	..	..	..	..	..	..	..	2	27
Congo, Rep.	..	..	48	..	..	..	..	0	0	..	..
Costa Rica	532	..	20	..	0.21	221	13	2	22	..	..
Côte d'Ivoire	..	..	31	..	..	..	..	0	16	..	..
Croatia	1,916	714	30	434	1.03	266	8	..	..	273	439
Cuba	1,612	1,121	16	..	0.84	..	..	..	..	109	23,162
Czech Republic	1,222	693	28	1,577	1.20	1,981	8	57	113	601	29,976
Denmark	3,259	2,644	25	3,513	1.95	5,479	18	..	..	2,658	106,403
Dominican Republic	..	..	35	..	..	2	1	0	25	..	..
Ecuador	146	42	27	..	0.02	20	4	0	68	8	302
Egypt, Arab Rep.	459	341	12	1,136	0.22	2	0	56	392	504	706
El Salvador	20	356	59	..	..	45	8	0	7	3	64
Eritrea	..	..	30	..	..	..	..	..	..	..	..
Estonia	2,017	391	27	..	0.57	173	9	1	7	18	26,626
Ethiopia	..	..	26	..	..	..	..	0	0	4 <sup>c</sup>	..
Finland	2,799	1,996	39	3,246	2.78	8,124	22	106	411	4,061	105,376
France	2,659	2,873	37	23,811	2.25	54,183	23	2,336	2,717	18,669	93,962
Gabon	234	22	29	..	..	17	..	..	..	..	..
Gambia, The	..	..	..	..	..	..	..	..	..	..	200
Georgia	..	..	39	..	..	..	..	..	..	265	26,561
Germany	2,831	1,472	47	30,654	2.41	63,698	14	3,252	4,893	62,052	113,543
Ghana	..	..	32	..	..	..	..	..	0	..	34,103
Greece	773	314	26	1,639	0.47	422	7	0	58	53	82,390
Guatemala	104	112	..	..	0.16	60	7	..	..	4	131
Guinea	..	..	34	..	..	..	..	..	..	..	..
Guinea-Bissau	..	..	0	..	..	..	..	..	..	..	25
Haiti	..	..	..	..	..	2	4	..	..	3	6
Honduras	..	..	24	..	..	2	1	0	5	10	126



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Hungary	1,099	510	32	1,469	0.68	3,891	21	46	215	774	29,331
India	149	108	25	7,851	0.73	1,314	5	19	201	10,155 <sup>c</sup>	..
Indonesia	182	..	39	..	0.07	2,120	10	..	..	..	4,517
Iran, Islamic Rep.	560	166	39	..	0.48	..	..	0	0	418 <sup>c</sup>	..
Iraq	..	..	41	..	..	..	..	..	..	68	18
Ireland	2,319	506	31	900	1.61	23,944	45	177	6,236	946	82,484
Israel	..	..	49	4,322	2.35	4,249	20	218	210	1,796	28,548
Italy	1,318	798	30	14,117	2.21	17,066	8	477	1,155	2,574	88,836
Jamaica	..	..	64	..	..	1	0	7	30	..	..
Japan	4,909	827	21	39,498	2.80	94,777	26	7,388	8,947	351,487	66,487
Jordan	94	10	26	..	0.26	..	..	..	..	..	..
Kazakhstan	..	..	20	..	0.32	103	9	..	..	1,171	24,998
Kenya	..	..	19	253	..	20	4	2	40	25	49,935
Korea, Dem. Rep.	..	..	..	..	..	..	..	..	..	..	25,467
Korea, Rep.	2,193	318	32	2,964	2.82	30,582	27	260	2,369	92,798	37,184
Kuwait	230	71	29	..	0.16	9	0	..	..	..	..
Kyrgyz Republic	584	50	14	..	0.20	31	16	..	..	152	24,951
Lao PDR	..	..	20	..	..	..	..	..	..	..	..
Latvia	1,049	351	23	..	0.43	42	4	2	7	163	26,860
Lebanon	..	..	30	..	..	..	..	..	..	..	..
Lesotho	..	..	19	..	..	..	..	20	1	..	49,483
Libya	..	493	..	..	..	..	..	..	..	12	23
Lithuania	2,028	631	31	..	0.70	71	3	0	6	125	26,673
Macedonia, FYR	1,335	546	47	..	..	11	1	1	2	66	26,087
Madagascar	12	37	25	..	0.18	1	1	1	10	..	26,174
Malawi	..	..	27	..	..	..	..	..	..	2	49,932
Malaysia	93	32	27	..	0.24	31,419	54	0	0	179	6,272
Mali	..	..	12	..	..	..	..	..	..	..	..
Mauritania	..	..	41	..	..	..	..	0	0	..	..
Mauritius	361	158	14	..	0.40	15	1	0	0	3	12
Mexico	214	74	32	1,408	0.33	19,266	19	139	454	429	35,503
Moldova	330	1,641	52	..	0.90	11	7	0	0	295	25,030
Mongolia	910	176	24	..	..	0	1	..	..	186	26,197
Morocco	..	..	41	..	..	9	0	7	171	90	237
Mozambique	..	..	42	..	..	2	6	..	..	..	..
Myanmar	..	..	56	..	..	..	..	..	..	..	..
Namibia	..	..	4	..	..	..	..	6	3	..	..
Nepal	..	..	13	..	..	..	..	0	0	..	..
Netherlands	2,219	1,358	39	9,239	2.08	35,377	30	2,432	2,964	5,227	85,402
New Zealand	1,663	809	20	1,830	1.04	471	..	44	267	1,735	33,402
Nicaragua	204	85	33	..	..	2	4	..	..	..	..
Niger	..	..	32	..	..	..	..	..	..	..	..
Nigeria	15	76	42	342	0.09	..	..	0	0	..	..
Norway	3,664	1,842	26	2,180	1.58	1,889	16	90	341	1,518	30,489
Oman	..	..	13	..	..	66	5	..	..	..	..
Pakistan	72	13	32	..	0.92	9	0	2	20	16	782
Panama	..	..	29	..	..	0	0	..	18	31	142
Papua New Guinea	..	..	10	..	..	..	..	..	..	..	..
Paraguay	..	..	20	..	..	4	2	185	1	..	..
Peru	233	10	34	..	..	35	3	8	80	48	756
Philippines	157	22	14	..	0.22	18,907	71	0	70	125	3,440
Poland	1,358	1,377	28	3,895	0.77	684	3	22	195	2,401	30,137
Portugal	1,182	167	36	764	0.62	812	4	41	290	92	106,595
Puerto Rico	..	..	..	..	..	..	..	..	..	..	..
Romania	1,387	581	21	..	0.72	117	2	3	21	1,709	27,346
Russian Federation	3,587	600	50	17,180	0.88	2,449	12	28	2	15,277	32,943



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Rwanda	35	8	28	..	0.04	..	..	0	1	..	..
Saudi Arabia	..	..	17	..	..	39	1	0	0	57	1,001
Senegal	3	4	21	..	0.01	..	..	0	2	..	..
Sierra Leone	..	..	17	..	..	..	..	..	..	..	9,506
Singapore	2,318	301	..	891	1.13	54,783	59	..	..	8,188	29,467
Slovak Republic	1,866	792	40	854	1.05	289	3	14	55	234	27,973
Slovenia	2,251	1,027	26	339	1.46	357	4	7	39	285	27,162
South Africa	1,031	315	29	1,744	0.70	923	9	72	165	..	..
Spain	1,305	343	31	8,811	0.90	5,635	7	243	1,866	2,856	110,911
Sri Lanka	191	47	34	..	..	..	..	..	..	81	26,322
Sudan	..	..	16	..	..	0	0	0	0	..	49,920
Sweden	3,826	3,166	38	7,190	3.76	13,725	20	1,114	939	7,893	107,107
Switzerland	3,006	1,374	34	5,896	2.60	12,030	16	..	..	5,814	107,038
Syrian Arab Republic	30	25	23	..	0.20	..	..	..	..	..	..
Tajikistan	666	..	17	..	..	..	..	..	..	23	24,742
Tanzania	..	..	37	..	..	0	0	1	5	..	..
Thailand	103	39	18	..	0.13	12,599	31	7	514	238	5,205
Togo	98	63	35	..	0.48	..	..	..	..	..	..
Trinidad and Tobago	..	..	58	..	..	13	1	0	0	17	26,322
Tunisia	125	57	33	..	0.30	104	2	11	3	46	128
Turkey	291	..	45	1,359	0.45	445	2	..	..	233	27,985
Turkmenistan	..	..	..	..	..	..	..	..	..	52	24,584
Uganda	21	14	17	..	0.57	..	..	0	0	..	49,760
Ukraine	2,171	575	42	2,489	..	..	..	..	..	4,692	28,036
United Arab Emirates	..	..	24	..	..	..	..	..	..	..	..
United Kingdom	2,448	1,017	34	32,980	1.95	64,461	28	6,724	6,123	26,591	121,618
United States	3,676	..	19	142,792	2.63	170,681	33	36,808	11,292	125,808	110,884
Uruguay	..	..	32	..	..	22	2	0	6	32	370
Uzbekistan	1,763	314	..	..	..	..	..	..	..	817	26,490
Venezuela, RB	209	32	26	..	0.49	79	3	0	0	201	2,323
Vietnam	..	..	..	..	..	..	..	..	..	30	27,410
West Bank and Gaza	..	..	..	..	..	..	..	..	..	..	..
Yemen, Rep.	..	..	5	..	..	..	..	..	..	..	..
Yugoslavia, FR (Serb./Mont.)	1,099	515	47	442	..	..	..	..	..	522	16,499
Zambia	..	..	16	..	..	..	..	..	..	..	96
Zimbabwe	..	..	24	..	..	13	2	..	..	3	21,966
<b>World</b>	<b>.. w</b>	<b>.. w</b>	<b>35 w</b>	<b>436,951 s</b>	<b>2.18 w</b>	<b>820,617 s</b>	<b>22 w</b>	<b>64,334 s</b>	<b>61,114 s</b>	<b>798,003 s</b>	<b>3,602,785 s</b>
<b>Low income</b>	257	..	35	14,646	0.57	25,475	13	106	688	23,772	648,006
Excl. China & India	..	..	..	595	..	2,167	..	24	67	831	573,943
<b>Middle income</b>	..	..	36	42,776	0.92	116,876	20	1,177	6,703	126,138	817,452
Lower middle income	..	..	37	23,775	..	24,762	17	395	1,688	27,027	449,771
Upper middle income	607	..	34	19,001	1.08	92,114	20	781	5,015	99,111	367,681
<b>Low &amp; middle income</b>	..	..	35	57,422	0.81	142,351	18	1,283	7,391	149,910	1,465,458
East Asia & Pacific	492	192	42	9,164	1.32	106,336	28	330	3,374	106,342	184,288
Europe & Central Asia	2,533	..	44	30,483	0.77	10,553	9	176	623	31,081	685,716
Latin America & Carib.	..	..	30	6,449	0.58	24,385	12	583	2,350	1,708	175,004
Middle East & N. Africa	..	..	29	1,136	..	107	1	73	566	509	1,207
South Asia	137	98	24	7,851	0.66	12	4	19	206	10,236	26,322
Sub-Saharan Africa	..	..	29	2,339	..	958	..	102	273	38	392,921
<b>High income</b>	3,166	..	25	379,529	2.36	678,267	33	63,051	53,723	648,093	2,137,327
Europe EMU	2,126	1,510	38	98,365	2.16	225,832	15	9,808	22,443	101,037	1,086,902

a. Other patent applications filed in 1997 include those filed under the auspices of the African Intellectual Property Organization (31 by residents, 26,057 by nonresidents), African Regional Industrial Property Organization (7 by residents, 25,724 by nonresidents), European Patent Office (44,604 by residents, 53,339 by nonresidents), and Eurasian Patent Organization (258 by residents, 26,207 by nonresidents). The original information was provided by the World Intellectual Property Organization (WIPO). The International Bureau of WIPO assumes no liability or responsibility with regard to the transformation of these data. b. Data are for the latest year available; see *Primary data documentation* for most recent year available. c. Total for residents and nonresidents.



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### About the data

Science is advancing rapidly in virtually all fields, particularly biotechnology, and playing a growing economic role: countries unable to access, generate, and apply relevant scientific knowledge will fall even further behind. And there is greater appreciation of the need for high-quality scientific input into public policy issues such as regional and global environmental concerns.

Science and technology cover a range of issues too complex and too broad to be quantified by any single set of indicators, but those in the table shed light on countries' "technological base"—the availability of skilled human resources (students enrolled in science and engineering, and scientists, engineers, and technicians employed in research and development, or R&D), the number of scientific and technical articles published, the competitive edge countries enjoy in high-technology exports, sales and purchases of technology through royalties and licenses, and the number of patent applications filed. Two of the indicators are new—science and engineering students and scientific and technical journal articles—and an updated methodology is used to calculate high-technology exports.

The United Nations Educational, Scientific, and Cultural Organization (UNESCO) collects data on scientific and technical workers and R&D expenditures from member states, mainly through questionnaires and special surveys as well as from official reports and publications, supplemented by information from other national and international sources. UNESCO reports either the stock of scientists, engineers, and technicians or the number of economically active persons (people engaged in or actively seeking work in any branch of the economy on a given date) qualified to be scientists, engineers, or technicians. Stock data generally come from censuses and are less timely than measures of the economically active population. UNESCO supplements these data with estimates of the number of qualified scientists and engineers by counting the number of people who have completed education at ISCED (International Standard Classification of Education) levels 6 and 7; qualified technicians are estimated using the number of people who have completed education at ISCED level 5. The data on scientists, engineers, and technicians, normally calculated in terms of full-time-equivalent staff, cannot take into account the considerable variations in quality of training and education. Similarly, R&D expenditures are no guarantee of progress; governments need to pay close attention to the practices that make them effective.

The data on science and engineering students refer to those enrolled at the tertiary level, which normally requires as a minimum condition of admission the successful completion of education at the secondary level.

These data are reported to UNESCO by national education authorities. (See *About the data* for table 2.10 for further details on UNESCO education surveys.)

The revised methodology used in this year's edition for determining a country's high-technology exports was developed by the Organisation for Economic Co-operation and Development in collaboration with Eurostat. Termed the "product approach" to distinguish it from a "sectoral approach," the method is based on the calculation of R&D intensity (R&D expenditure divided by total sales) for groups of products from six countries (Germany, Italy, Japan, the Netherlands, Sweden, and the United States). Because industrial sectors characterized by a few high-technology products may also produce many low-technology products, the product approach is more appropriate for analyzing international trade than is the sectoral approach. To construct a list of high-technology manufactured products (services are excluded), the R&D intensity was calculated for products classified at the three-digit level of the Standard International Trade Classification revision 3. The final list was determined at the four- and five-digit level. At this level, since no R&D data were available, final selection was based on patent data and expert opinion. This methodology takes only R&D intensity into account. Other characteristics of high technology are also important, such as know-how, scientific and technical personnel, and technology embodied in patents; considering these characteristics would result in a different list. (See Hatzichronoglou 1997 for further details.)

The counts of scientific and technical journal articles include those published in a stable set of about 4,800 journals selected by the Institute of Scientific Information as the base of its Science Citation Index in 1981 and published by the National Science Foundation. (See *Definitions* for the fields covered.) The Institute of Scientific Information's database covers the core set of scientific journals, but may exclude some of regional or local importance. It may also reflect some bias toward English-language journals.

Most countries have adopted systems that protect patentable inventions. Under most patent legislation, to be protected by law (patentable), an idea must be new in the sense that it has not already been published or publicly used; it must be nonobvious (involve an inventive step) in the sense that it would not have occurred to any specialist in the industrial field, had such a specialist been asked to find a solution to the problem; and it must be capable of industrial application in the sense that it can be industrially manufactured or used. Information on patent applications filed is shown separately for residents and nonresidents of the country. The World Intellectual Property Organization estimates that at the end of 1996 about 3.8 million patents were in force in the world.

### Definitions

- **Scientists and engineers in R&D** are people trained at the tertiary level to work in any field of science who are engaged in professional R&D activity.
- **Technicians in R&D** are people engaged in professional R&D activity who have received vocational or technical training in any branch of knowledge or technology. Most of these jobs require three years beyond the first stage of secondary education.
- **Science and engineering students** include students at the tertiary level in the following fields: engineering, natural science, mathematics and computers, and social and behavioral science.
- **Scientific and technical journal articles** refer to the number of scientific and engineering articles published in the following fields: physics, biology, chemistry, mathematics, clinical medicine, biomedical research, engineering and technology, and earth and space sciences.
- **Expenditures for R&D** are current and capital expenditures on creative, systematic activity that increases the stock of knowledge. Included are fundamental and applied research and experimental development work leading to new devices, products, or processes.
- **High-technology exports** are products with high R&D intensity. They include high-technology products such as in aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery.
- **Royalty and license fees** are payments and receipts between residents and nonresidents for the authorized use of intangible, nonproduced, non-financial assets and proprietary rights (such as patents, copyrights, trademarks, industrial processes, and franchises) and for the use, through licensing agreements, of produced originals of prototypes (such as manuscripts and films).
- **Patents** are documents, issued by a government office, that describe an invention and create a legal situation in which the patented invention can normally be exploited (made, used, sold, imported) only by, or with the authorization of, the patentee. The protection of inventions is generally limited to 20 years from the filing date of the application for the grant of a patent.

### Data sources

The data on technical personnel, science and engineering students, and R&D expenditures are from UNESCO's *Statistical Yearbook*. The data on scientific and technical journal articles are from the National Science Foundation's *Science and Engineering Indicators 1998*. The information on high-technology exports is from the United Nations' Commodity Trade (COMTRADE) database. The data on royalty and license fees are from the International Monetary Fund's *Balance of Payments Statistics Yearbook*, and the data on patents from the World Intellectual Property Organization's *Industrial Property Statistics*.