South Asia

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South Asia remains one of the world's poor regions in 2005. Harnessing science and technology (S&T) to human development and economic growth over the past decade has proved a difficult task for many countries with a growing population. Even though poverty levels have dropped in India and other countries of the region in the past five years, human development indicators have witnessed only minor improvements for South Asia as a whole. With the possible exception of India, government support for scientific research and development (R&D) has remained relatively low, at between 0.2% and 0.5% of gross domestic product (GDP) for the region as a whole. This compares with gross domestic expenditure on R&D (GERD) of 1.5–2.5% of GDP in East Asian countries during the decade.

For many countries in the region, the main agenda for S&T remains the development of institutions and universities, and the institutionalization and professionalization of science. In many ways, the general underdevelopment of national scientific communities is no more than a reflection of the low priority accorded to investment in S&T for development. It is thus not surprising that biotechnologies, microelectronics, and information and communication technologies (ICTs), among others, have simply bypassed most countries in the region. The ongoing globalization and liberalization processes have compounded these problems. At the global level, access to new and frontier technologies has become both difficult and very expensive on account of intellectual property regimes. Furthermore, growing technological competition has led to market and technology protection in the developed countries, making it even more difficult for developing countries to integrate new technologies.

Although the industrial and service sectors have shown encouraging growth rates over the past five years, contributing an ever greater proportion of GDP, more than 65% of South Asians remain dependent on agriculture and closely related sectors such as food processing, fisheries, animal husbandry and commercial crops. For this reason, building technological capacities in agriculture for food security invariably confers importance on the agricultural and modern biological sciences. The manufacturing and service sectors, which are likely to play a key role in the industrialization and modernization of South Asia, pose additional problems for national innovation systems.

HUMAN DEVELOPMENT SCENE

One of the major social concerns of South Asia is growing poverty. Of the total population of 1.5 billion, some 467.5 million – one-third of South Asians – live below the bread line. The trend towards a reduction in poverty witnessed throughout the region since the 1970s did not survive the 1990s, with the possible exception of India. Poverty has grown in Bangladesh, Nepal, Pakistan and urban Sri Lanka. Even in India, the numbers of the absolute poor, which had remained stable at between 294 and 315 million from 1970 to 1994, hit the 328 million mark in 2000. All but the Maldives are listed after the first 90 countries in the UNDP's Human Development Index assessing 177 nations (the Maldives holds the 84th position) (UNDP, 2004).

The structure of poverty becomes even more glaring when we take into account other human development indicators. Some 323 million people in South Asia do not have access to health services, 458 million are deprived of safe drinking water and 867 million continue to live without sanitation. With the exception of Iran, these human development problems are deepening in South Asia in the new millennium.

The figures for children (under the age of five) who are underweight for their age speak for themselves: 48% in each of Bangladesh and Nepal, 47% in India, 38% in Pakistan, 29% in Sri Lanka, 19% in Bhutan, 13% in Mongolia and 11% in Iran. One-third of the population in Bangladesh (36%), Nepal (38%) and India (35%) lives on just US$ 1 per day. Extreme poverty is less widespread in Mongolia and Sri Lanka, where 14% and 7% respectively of their populations live below the breadline (UNDP, 2004).

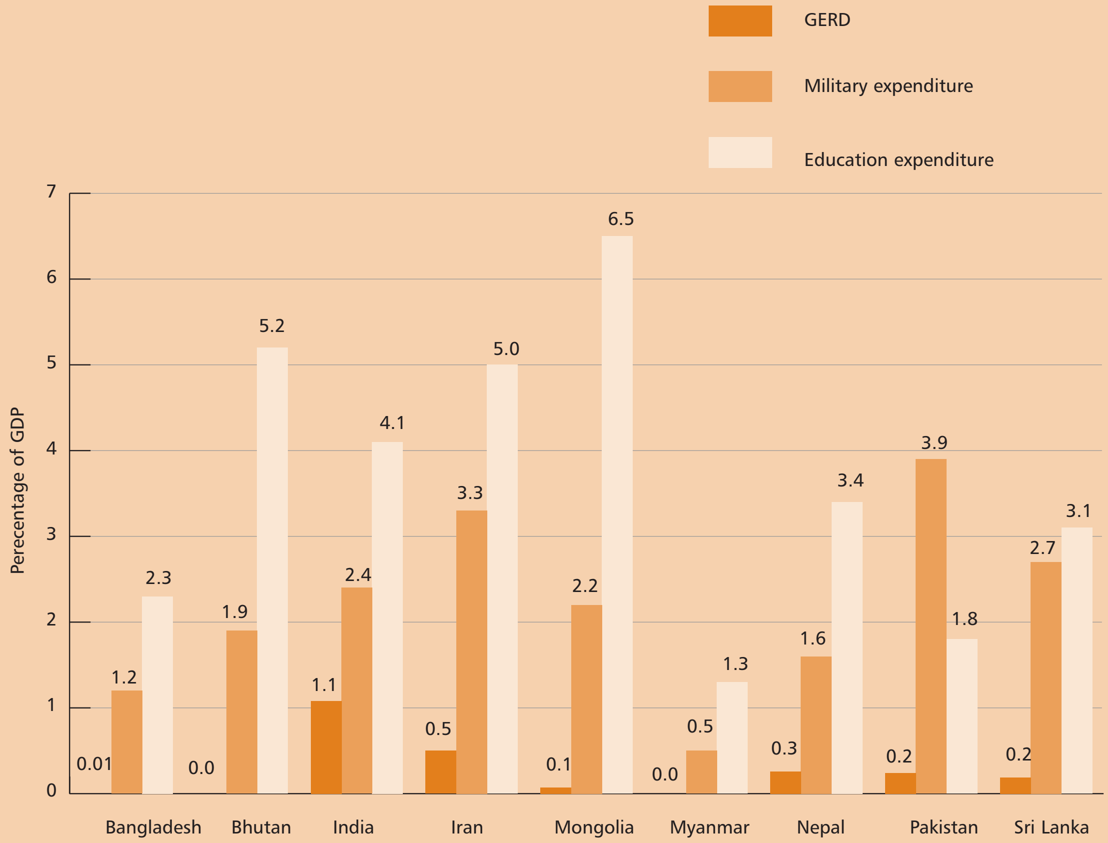
There are however some positive signs. The major human development indicators in health and education reveal that average life expectancy has improved dramatically, from an average 40–44 years in 1960 to 60–64 years in India, Bangladesh and Pakistan and higher in Sri Lanka (73) and Iran (70) in 2001 (UNDP, 2004). Similarly, all countries have made great strides in improving adult literacy over the past three decades, although the task remains enormous for some, particularly with regard to female literacy (the figures for women are in brackets): India 61.3% (breakdown by gender unavailable), Pakistan 41.5% (28.5%), Bangladesh 41.5% (31.4%), and Nepal 44.0% (26.4%) (UNESCO, 2005). The major challenge for improving basic education in South Asia falls to Indian planners, as about 300 million adults in India were still illiterate in 2002–03, out of a total of 402 million illiterates for the entire region. The best indicators of adult literacy in South Asia come from Iran at 76.0% (68.9%), the Maldives at 97.2% (97.2%) and Sri Lanka at 92.1% (89.6%) (UNESCO, 2003; 2005).

Closely associated with adult literacy is the critical indicator of national support for education, reconceptualized as ‘human capital’ defined as ‘the stock

Figure 1

GERD, MILITARY AND EDUCATION EXPENDITURE IN SOUTH ASIA, 2000–04*

As a percentage of GDP



* GERD figures for Iran, Pakistan and India are for 2002; for Bangladesh and Sri Lanka for 2000; for Mongolia 1997; and for Nepal 2004. Myanmar military . expenditure is for 2001.

Sources: for military expenditure as % of GDP for South Asian countries for 2004http://www.photius.com/rankings/military/military_expenditures_percent_of_gdp_2004_1.html; for education expenditure for India, Pakistan, Sri Lanka and Bangladesh for 2001–02,http://www.adb.org/Education/haugh-sin.pdf and http://hdr.undp.org/statistics/data/indic/indic_180_1_1.html; for Nepal, Nepal Academy of Sciences 2004.

of useful, valuable and relevant knowledge built up in the process of education and training' (Human Development Centre, 1998, p. 25). From such a perspective, a relative stagnation or at best marginal increase (when adjusted for inflation) can be seen in the national education budgets of countries between 1980 and 1996. In India, the decade-long goal of spending 6% of GDP on education has still not been reached, with the education budget witnessing only a modest increase from 3% in 1980 to 4% in 2000–04. Whereas Pakistan has witnessed a marginal decrease in spending on education, from 2% to 1.8%, Nepal has increased spending on education, from 2% to over 3% between 1980 and 2000–04. Over the same period, during the first half of which the Iran–Iraq war was raging, there was a dramatic decline in Iran's education budget, from 7.5% to 5.0% of GDP (Figure 1). Bangladesh and Sri Lanka almost doubled the share of GDP devoted to education over the same period. In Bangladesh, where non-governmental organizations (NGOs) have played an important role, the number of primary schools increased from 47 000 to 63 000 between 1980 and 1996, with a corresponding improvement in the enrolment of pupils (aged 6–10) from 10 million to 14 million (Human Development Centre, 1998, p. 56). Despite drastic cuts in military expenditure, other countries in the region have not managed to raise their education budgets.

THE ECONOMIC CONTEXT

Until the late 1980s, most countries in the region followed a development strategy which promoted industrialization based on import substitution and self-reliance. Since the early 1990s, there has been a shift away from an 'inward looking' policy – with the possible exception of Iran – towards one based on economic liberalization fostering globalization and export. The growth outlook for 2004–05 and beyond is not discouraging, as GDP is expected to grow by 6–7%, the second-fastest rate after China. This has promoted an inflow of capital, technology and partnerships with foreign firms, triggering a shift in the composition of the production structure. As shown by the data from the

Table 1
TRENDS IN ECONOMIC ACTIVITY IN SOUTH ASIA, 1980s–2002

	Sectoral composition of production (% GDP)						**Sectoral share of labour force (% of total)**					
	Agriculture		**Industry**		**Services**		**Agriculture**		**Industry**		**Services**	
	1980	**1995–2002**	**1980**	**1995–2002**	**1980**	**1995–2002**	**1985–86**	**2002**	**1985–86**	**2002**	**1985–86**	**2002**
Bangladesh	49.4	17.6	14.8	27.9	35.8	54.6	56.5	62.0	11.5	10.0	33.7	24.0
Bhutan	56.7	30.3	12.2	39.2	31.1	33.6	–	94.0	–	1.0	–	5.0
India	38.1	23.4	25.9	23.8	36.0	54.9	65.0	67.0	10.0	13.0	26.6	20.0
Iran	18.0	12.0[2]	32.0	39.0[2]	50.0	49.0[2]	36.4	23.0[3]	32.8	32.0	30.8	45.0
Maldives	31.0	7.2	6.0	20.8	63.0	72.0	–	22.0[4]	–	18.0	–	60.0
Mongolia	15.0	33.0[1]	33.0	28.0[1]	52.0	–	39.8	32.0[1]	21.0	23.0[1]	39.2	45.0[1]
Myanmar	47.0	59.0[1]	13.0	10.0[1]	40.0	–	–	63.0	–	21.0	–	16.0
Nepal	61.8	39.2	11.9	20.8	26.3	43.9	93.0	81.0[5]	0.6	3.0[5]	6.4	6.0[5]
Pakistan	30.6	22.3	25.6	21.2	43.8	56.4	49.6	48.0	12.4	18.0	38.0	34.0
Sri Lanka	26.6	21.4	27.2	24.7	46.2	54.0	49.8	42.0	18.8	23.0	32.2	35.0
South Asia	37.8	24.6[1]	25.0	30.2[1]	37.2	55.2[1]	62.8	64.6[1]	10.6	14.8[1]	27.2	18.6[1]

Notes:
1 Data for 1997.
2 Data for 2002 from Encarta.msn.com/encyclopedia–761567300_3/Iran.html
3 Data for 1996.
4 www.mapquest/com/atlas/main.adp?/region=maldives
5 Data for 1999, source as 4 above.

Other sources: UNESCO (1998) *World Science Report 1998*; RIS (2003) *SAARC Survey of Development and Cooperation 2002–2003*; Asian Survey (1999) *Asian Survey* 39(1) p.115–69; for 1997 GDP in India see *Economic Times*, 27 January 2000, New Delhi; for 1997 GDP in Iran see PBO/UN (1999) *Human Development Report of the Islamic Republic of Iran.*

seven-nation South Asian Association of Regional Cooperation (SAARC), where the share of agriculture in GDP declined between 1980 and 2002, there was a corresponding increase in the shares of industry and services (Table 1). The services sector has emerged as the main motor of development in the region, contributing more than half of economic growth as a whole in South Asia. Despite this shift, South Asia remains an agrarian economy, with around 64% of the labour force and population being dependent on agriculture.

The industry and services sectors of the SAARC region witnessed steady growth from 1981 to 1999. Whereas agriculture grew at an average rate of 2.3% over this period, the industrial and services sectors registered average growth of about 6%, making South Asia one of the fastest-growing regions in the world. The services sector is likely to assume considerable importance in the region, which has performed quite impressively in the past decade with an average growth rate of 6.9%. It is something of a paradox that, even though the services sector's composition of GDP increased considerably between 1986 and 2002, its share of the labour force registered a decline. This indicates that modernization processes are not creating employment in this sector at a pace with population growth. The transformation from an economy based on agriculture to one based on industry and services seems likely to persist in the years to come but what is also evident is the significant role played by the small and medium-scale manufacturing sectors, as opposed to engineering and heavy industry.

Despite the slowdown in the share of the labour force employed in industry and services between 1986 and 2002 for South Asia as a whole, there has been a remarkable shift in the composition of GDP in industry and services. With the exception of Bhutan and Nepal, the contribution of the services sector to GDP in South Asian countries has crossed the 50% threshold. Dramatic changes in the services sector can be seen above all in India, thanks mainly to the Indian information technology (IT) industry, which recorded a compound annual growth rate of more than 41% from 1994 to 1999 before sliding back to around 32% by 2004. The IT market crossed the US$ 19 billion mark in 2004 and is expected to reach US$ 50 billion by 2008. The future looks promising: a source in the Ministry for Information Technology indicates that, by 2008, some 35% of India's total foreign exchange earnings are likely to come from software exports, providing employment opportunities for 2.2 million people and a market capitalization of US$ 225 billion (Kumar, 2000).

In Iran between 1995 and 1998, agriculture registered average growth of 3.6%, manufacturing 2.4% and services 5.4%. Iran used to rely heavily on revenue generated by oil exports but, after years of declining oil revenues from 1975 onwards, development plans began to focus on manufacturing and industry in the late 1990s. Long-standing protection policies continue to place a heavy burden on economic dynamism, particularly on the inflow of foreign direct investment and technology. Growth in engineering and high technology is severely hampered by

Table 2
SCIENTISTS AND ENGINEERS IN SOUTH ASIA, 2000–04

Country	Total population (millions) 2003	Scientists and engineers per million population*
Bangladesh	138	51
Bhutan	2	–
India	1 064	157
Iran	67	590
Mongolia	3	1 370
Myanmar	48	–
Nepal	25	40
Pakistan	148	69
Sri Lanka	19	191

* Full-time equivalent.

Source: for population data: www.worldbank.org/data/databytopic/sas-wdi.pdf and www.sarid.net/development/index.htm#statistics; for scientists and engineers: World Bank (2002, 2003) *World Development Report*; National Science Foundation, Colombo; Pakistan Council for Science and Technology, Islamabad; Department of Science and Technology, New Delhi; BANSDOC, Dhaka; Ministry of Science and Technology, Education and Culture of Mongolia; PBO (Iran 1400 Committee), IROST, Iran.

the concentration of industry in the state sector. These 'inward-looking' policies have prevented both competition and the dynamic growth of the private industrial sector (PBO/UN, 1999).

S&T EFFORT

The consideration of S&T and higher education as a crucial factor in the processes of development, modernization and industrialization is clearly evident from the national plans of individual governments in South Asia. Each country has created a Ministry of Science and Technology, often included in the portfolio of education. On the surface, this indicates that importance is being assigned to S&T. Unfortunately however, there is a continuing gulf between appearances and reality. The formal importance given to S&T policies has not translated into real investment. The 'historic' figure of devoting 1% of GDP to R&D for developing countries, advocated by numerous international and national agencies since the 1979 Vienna Conference on Science and Technology for Development, is still a pipe dream for most countries in South Asia.

COUNTRY PROFILES

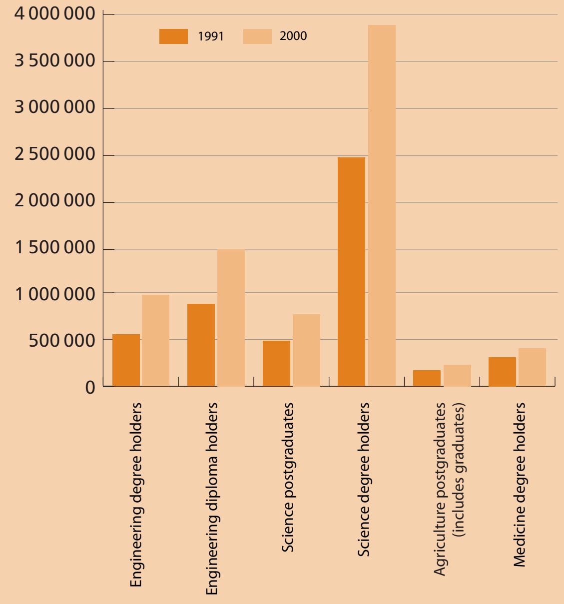
India

Among its South Asian neighbours, India stands out in terms of national investment in R&D and endowment of S&T human resources; it also maintains the lead in S&T publications. S&T policies in India have always stressed the development of human resources. As Figure 2 shows, all categories of S&T personnel have increased over the past decade. The number of universities has also grown substantially, from 209 in 1990 to more than 300 in 2005, thanks to the decision of the University Grants Commission to authorize several private universities. Moreover, seven Indian universities figure prominently in the list of Asia's top 20 universities in 2000 (Table 3).

In terms of S&T publications, even though India maintains a big lead in the South Asian region, the past 15 years have witnessed a notable decline, particularly between 2000 and 2004 (Figure 4). It is interesting to note that, whereas resident Chinese authored fewer than one-third of the number of papers Indian scientists published in the mid-1980s (3 238 compared to India's 11 222 in 1985), China has now overtaken India, with a remarkable 22 061 publications now registered in the Science Citation Index (SCI) of the Institute of Scientific Information in Philadelphia (USA), compared with India's 12 127 (Arunachalam, 2002). Even though S&T policy has focused on intellectual property management favourable to patents in the past five years, the relative stagnation and decline in S&T output, as measured in terms of papers, has generated debate in Indian S&T circles.

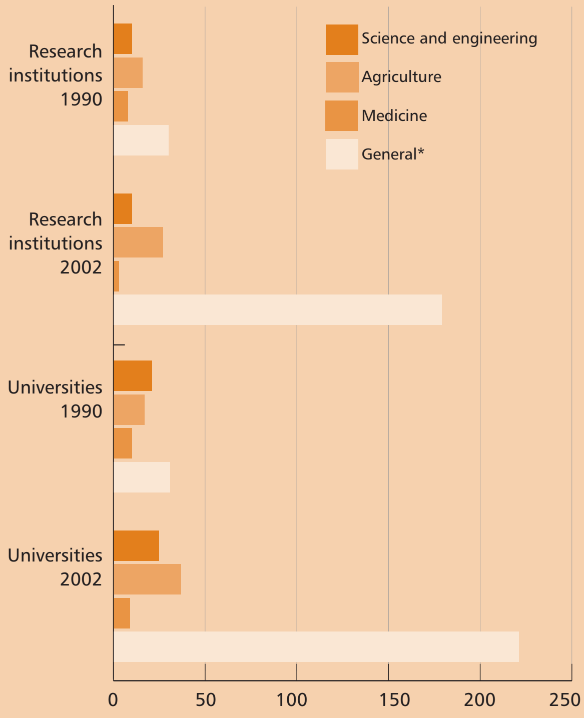
However, the most notable development for India has been the crossing of the historic threshold of 1% for the GERD/GDP ratio in 2004 (matching the achievement of China). India had always given high priority to S&T and

Figure 2
HUMAN RESOURCES IN S&T IN INDIA, 1991 AND 2000
By degree and field of study



Source: Department of Science and Technology, Government of India, 1999; 2002.

Figure 3
RESEARCH INSTITUTIONS AND UNIVERSITIES IN INDIA, 1990 AND 2002
By field



* Indicates major universities and other institutions teaching science, engineering, technology, medical and social sciences.

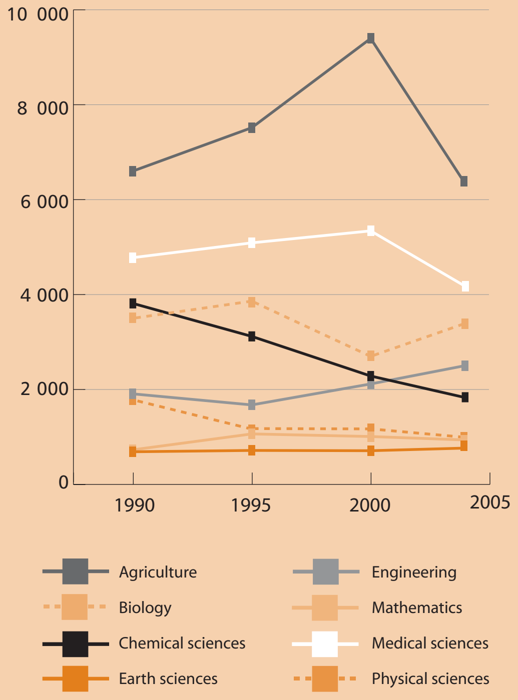
Sources: *Universities Hand Book*, New Delhi; Association of Indian Universities, 2002.

higher education, a trend set by Jawaharlal Nehru, India's first Prime Minister. In line with this tradition, the current Indian Prime Minister, Manmohan Singh, underlined government's commitment to S&T policy at the 92nd session of the Indian Science Congress at Ahmedabad in 2005. Among the important policy commitments, the following are noteworthy:

- development of basic science, applied science and the promotion of excellence;
- rebuilding the science base in universities;
- fostering public–private partnerships;
- debureaucratization of S&T institutions and preservation of academic autonomy; and
- creation of exciting career opportunities for scientists to keep talent at home and to sustain it through the expansion of a dozen main centres of excellence, such as the Indian Institute of Science in Bangalore, one of the country's oldest institutions of learning and research (dating from 1909).

Other recent government initiatives of note include the launch of the Nanoscience and Technology Initiative, with funding of billion Rupees (Rs)[1]; a budgetary allocation of

Figure 4
INDIAN SCIENTIFIC OUTPUT IN TERMS OF PUBLICATIONS, 1990–2004
By field



Note: Agriculture includes animal husbandry, forestry and fisheries; biology includes botany and zoology.

Source: INSDC, *Indian Science Abstracts*, 1965–2000. New Delhi: Indian National Scientific Documentation Centre. (Various issues for respective years.)

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[1] 43 Indian Rupees (Rs) were equivalent to US$ 1 in June 2005.

Rs 1 000 million to the Indian Institute of Science in Bangalore to bring its science base up to a par with the best in the world; new Millennium Indian Technology Leadership Initiatives to boost the capacity for innovation in new technologies of the Council for Scientific and Industrial Research (CSIR); a National Innovation Foundation to be run by the Department of Science and Technology (DST); and two major schemes devised by the DST to promote the commercialization of research results and provide venture capital for economically viable technologies and R&D processes developed in national laboratories.

Indian efforts to promote S&T over the past decade have contributed to the country's emergence as an important 'knowledge power' in the global economy. While inaugurating a ceremony to celebrate India's prestigious Shanti Swarup Bhatnagar Awards in New Delhi in 2004, the prime minister proudly observed that India ranked 24th out of 192 (Rand Corporation Classified) scientifically proficient nations. Much of this is due to achievements in the four main science-based knowledge sectors: space technologies (including aerospace); ICT software; biotechnology; and drugs and pharmaceuticals.

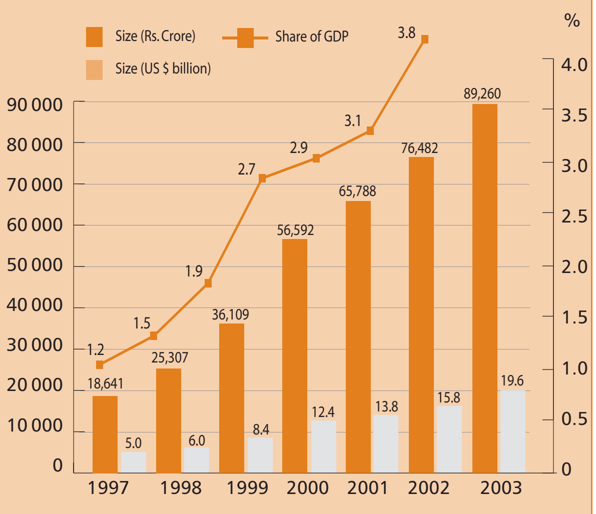
The heyday of Indian space research can be traced back to the launch of the Indian National Satellite System (INSAT) in the early 1980s with a unique system combining telecommunications, TV broadcasting, meteorology and disaster warning. Today, INSAT has become one of the largest satellite systems in the world. Over the years, India has developed sophisticated, high-tech capabilities endogenously in the design and construction of satellites, ground stations, rockets and satellite launch platforms, as well as in software and hardware electronics and telecommunications. In 2000, India launched the third generation INSAT 3B satellite; in 2001, the Polar Satellite Launch Vehicle (PSLV), capable of launching satellites of 1 000–1 200 kg into the 820km polar sun-synchronous orbit; and, from 2001 onwards, the Geosynchronous Satellite Launch Vehicle (GSLV), which can put satellites into approximately 180 x 32 155km geo-synchronous transfer orbit. The PSLV-C2 version has launched two small satellites, one off the Republic of Korea and another off Germany, along with India's IRS-P4 in May 1999. Among other significant launches mention may be made of the educational network satellite (EDUSAT) successfully launched on 20 September 2004 from the GSLV platform at Sriharikota, and the CARTOSAT-1 and HAMSAT satellites for mapping and radio networks launched successfully from the PSLV platform at Sriharikota on 5 May 2005.

India's **space research** in the past five years has come to play a major social and economic role: 85% of India's 1 billion plus population now has access to television via the INSAT system. INSAT can also track weather patterns and contribute to early warning of natural disasters. The INSAT system has become an important educational tool for addressing the mass illiteracy problem by offering *in situ* training for industrial workers and agricultural farmers. Space research systems are contributing to natural resource management and to tracking groundwater and mineral resources. India is now set to lend its space technological capabilities to the commercial launching of satellites. Already, it is playing an important role in the region through its commercial wing, the ANTRIX Corporation Ltd. This provides telemetry, tracking and command (TTC) support services, in-orbit test and support services, specialized training and various other types of services and technical consultancy related to space systems, technology and applications. The company made steady, significant progress over the years in terms of financial performance, with sales turnover exceeding Rs 3 billion.

Closely related to space technology is aerospace research and innovation. The launch of the endogenously built civilian aircraft model, SARAS, and light combat aircraft in the past three years offers further testimony to progress in this field.

The second sector to have changed the image of India abroad in recent years is ICT, and specifically the **software** sector. It is no accident that the *New Scientist* refers to India in its issue of 19 February 2005 as emerging as 'the next knowledge superpower', drawing much of its evidence from the ICT software sector. Whereas more than 100 of the Fortune 500 firms have already set up R&D antennae in ICT and other high technology areas in India in the past five years, Indian software companies in 2005 are providing all kinds of IT services (known as business process outsourcing and IT-enabled services) to 400 of these premier global firms. Currently, about 3 000 IT companies are exporting to over 150 countries around the world. As Figure 5 shows, India's software market has quadrupled in six years to US$ 20 billion in 2004, accounting for about 3.82% of India's GDP, compared with 1.22% in 1998. India's software exports are estimated to rise from the current US$ 12.5 billion to US$ 30 billion by 2008. Contrary to common wisdom about the Indian software sector, which is viewed as being driven solely by global production networks and exports, these figures clearly indicate the rapid evolution of India's domestic IT market. The market is undoubtedly a key factor in the development and growth of the IT software sector but government efforts and those of non-governmental organizations (NGOs) to bridge the digital divide have generated encouraging results in the past decade.

Figure 5
INDIA'S IT INDUSTRY AND MARKET, 1997–2003



Source: NASSCOM.

The M.S. Swaminathan Foundation in Chennai has developed a model for a 'bio-village', where information technology is introduced to help rural people develop communication skills and add value through knowledge to agricultural systems, bio-resource and biotechnology. Among other important developments, some of the most recent are the development and commercialization of SIMPUTER, an Indian-made simple, cost-effective computer which can be held in the palm of the hand and which is priced at less than $US 150; a second example is a laptop with a purchase price of less than US$ 200. These products are the result of public–private partnerships in ICT to help the poor access and benefit from the information revolution.

The domestic IT market in India owes its rapid growth to big e-governance projects launched by both the central government and various state governments; these have been designed to computerize revenue and taxation, land records, motor vehicle registration and the issue of licences, payrolls and salary disbursements, transport networks and so on. Further, as R.A. Mashelkar, FRS, the Director-General of CSIR, observed in an interview with Gurusonline TV in February 2005, 'in the last three years, Indian exports have increased tremendously not only because of the cost advantage but mainly due to quality aspects. India's basic strength arises from the quality of its human resources'. There are about 4 000 IT training centres (1 700 of which are privately owned) and 1 208 engineering colleges imparting education in IT and related engineering fields. Currently, about 290 000 engineering professionals are employed in firms and institutions in India. According to a survey published by the *India Times* News Network on 16 June 2005, the IT industry has witnessed rapid growth of other software and service employees, whose numbers tripled to 697 000 between 2001 and 2004.

The third sector to have drawn sharp attention in the last five years is the Indian **pharmaceutical industry**, which is said to be the fifth largest in the world after those of the USA, Japan, Europe and China in terms of the volume of production; the Indian pharmaceutical industry accounts for 8% of the world total (Lalitha, 2002). Some 350 of the 550 bulk drugs are currently produced in India and the country is self-sufficient in every essential drug. One important indicator for the success of this sector can be seen from the trend in exports. The industry moved from a negative balance of trade in the late 1980s to a positive balance of trade of Rs 39 060 million by the late 1990s and Rs 65 000 million in the year 2003, according to the Indian Drugs Manufacturing Association. In a large measure, the relative success of this sector can be attributed to the uniqueness of the Indian Patent Act of 1971, which until 2005 (see page 252) had given protection to process patents for seven years (compared with the product-based 20-year period of patent protection elsewhere) to encourage what is known as 'reverse engineering' (see also Lalitha, 2002; Ramani, 2002). This enabled the country to indigenize almost all the essential drugs by building S&T capabilities in chemical and drug research in government research laboratories and firms; meanwhile, the requisite human resources were gleaned from the expansion of higher education.

One important feature of the Indian pharmaceutical sector has been the evolution of technological capabilities. These have passed through the successive stages of technology support, technology development (based on reverse engineering), building up capabilities for drug discovery, and the exploitation of the innovation base for the purposes of commercialization. If Indian-invented US patents and Patent Cooperation Treaty (PCT) applications are taken as one key indicator of success in recent years, it is edifying to learn that more than 70% of the 300 US patents in pharmaceuticals granted from the 1990s to 2002 were issued to Indian firms and institutions. On the other hand, the number of PCT applications doubled from 1 099 in 1998 to over 2 000 for the period 2000 to 2003 (see also Lalitha, 2002; Hirwani, 2004). More than half of these patents and PCT applications are accounted for by government laboratories, a sign of the crucial role played by public research in the Indian context. The most important development in the past decade has been the emergence of over a dozen Indian pharmaceutical and biopharmaceutical firms. These are involved in R&D activities, as demonstrated by their patenting and drug manufacturing activities showing increasing technological sophistication. For instance, an Indian company recently offered an anti-HIV 'cocktail' for the price of US$ 300, compared with US$ 10 000 in the marketplace.

The fourth sector of note is one that is increasingly meshing with the drugs and pharmaceuticals industry, namely **biotechnology**. In many ways the biotechnology industry follows the development of new software. Created in the early 1980s, the Department of Biotechnology (DBT) has been the main driver of the biotechnology sector in that it has been at the forefront of efforts to develop human resources and generate public funds for research. Government funding for the sector increased about fourfold between the late 1990s and 2004. Currently, more than 60 universities offer postgraduate courses in biotechnology and related programmes and about half of these are funded by the DBT through the creation of specialized chairs and infrastructural facilities for research. In addition to this, the DBT supports doctoral and postdoctoral fellowships for students in India and studying at foreign universities, mostly in the USA, as part of its support to frontiers in biotechnology.

The DBT has given top priority to developing the human resources base in biotechnology. The Vision Document published by the DBT in 2001 underlines the importance of training 1 000 additional professionals per year for the next ten years to generate a professional workforce of 15 000 to 20 000, in order to meet the growing demands of the sector. Between 1991 and 2002, the number of research publications and patents in the biotechnology sector doubled (Kumar *et al.*, 2004; TIFAC, 2004). Over the same period, the government budgetary allocation to DBT increased almost fourfold, from Rs 740 million in 1991 to about Rs 2 800 million in 2004 (Department of Biotechnology, New Delhi).

Other science agencies, such as the CSIR, Indian Council of Medical Research, Indian Council of Agricultural Research, DST and Ministry of Forests and Environment, are supporting

Indian Institutes of Technology

India boasts seven Indian Institutes of Technology (IITs), in Kharagpur, Mumbai (Bombay), Chennai (Madras), Kanpur, New Delhi, Guwahati and Roorke. The IITs run departments offering programmes of study in both engineering and pure sciences to ensure that future engineers acquire a thorough grounding in the basic sciences. Programmes are also proposed in interdisciplinary areas. All seven IITs conduct sponsored basic and applied research and offer industrial consultancy services to the public and private sectors, including a number of multinational companies. They also engage in collaborative research with leading domestic and foreign universities (including institutions in Bangladesh, Canada, Germany and the UK). Examples of research centres run by the IITs are the Centre for Robotics, Centre for Laser Technology and Advanced Centre for Materials Science (IIT Kanpur), and the Composites Technology Centre and Biotechnology Research Centre (IIT Chennai).

The IITs concentrate some of the most promising talent in the country. Fewer than 1% of the 250 000 hopefuls obtain a place each year, an acceptance rate that excludes all but the most excellent students and explains why US universities are so eager to recruit IIT students for their own campuses. In comparison, the acceptance rate is more than 10% for the best US universities (Rajghatta, 1999).

The information revolution has made millionaires of many former IIT students. It has also earned them an international reputation for excellence. In 2000, IITs occupied five of the first eight places in a survey by *Asiaweek* magazine of S&T universities in Asia (Table 3).

IIT graduates are today the object of intense courtship by US universities, which woo them with the lure of scholarships, a housing allowance or a paid internship in an American company. The strategy would appear to be working: an estimated 20 000 IIT graduates are living in the USA alone, about 20% of all graduates produced by the institutes since their inception 50 years ago. According to *Businessweek* magazine published in the USA, as many as 30% of IIT Madras graduates headed for the USA in 1998. This brain drain is now being counterbalanced by the return of professionals to India (a form of brain gain and brain circulation) to surf the on-going revolutions in ICT and biotechnologies. According to one estimate (interview with a professor at the IIT Delhi, 5 July 2005), these professionals together with Indian-owned companies from Silicon Valley, USA, are reported to have created approximately about 200 small- and medium-sized start-up businesses in Bangalore, Hyderabad, Pune, Delhi and other Indian cities.

There are plans to inject US$ 1 billion into the IITs to improve their infrastructure and the quality of research. This is the amount considered necessary to extend the reach of the IITs to a greater number of hopefuls and bring faculties up to the standard of the best universities in the USA, such as Harvard and the Massachusetts Institute of Technology (MIT). Partial funding is expected to come from IIT alumni in the USA and elsewhere. Although this may be a novel approach for the IITs, it is common practice for Harvard and the MIT, which have long since discovered that wealthy alumni make generous benefactors (Goel, 2000).

At the first Global IIT Alumni Conference in January 2003, organized in the heart of Silicon Valley in the state of California (USA), Bill Gates, Chairman of Microsoft Corporation, gave the inaugural address. The second Global IIT Alumni Conference is also scheduled to take place in the USA, in Washington, DC in May 2005. The declared goal of the conference is to foster joint research between the IITs and US industry, academia and government, promote networking among alumni and ‘to help IITians give back to their communities’ (see www.iit2005.org).

Table 3
THE TOP 20 S&T UNIVERSITIES IN ASIA, 2000

Ranking	**Country/ territory**	**University**
1	Republic of Korea	Korea Advanced Institute of Science and Technology
2	Republic of Korea	Pohang University of Science and Technology
3	India	Indian Institute of Technology, Bombay
4	India	Indian Institute of Technology, Delhi
5	India	Indian Institute of Technology, Madras
6	Japan	Tokyo Institute of Technology
7	India	Indian Institute of Technology, Kanpur
8	India	Indian Institute of Technology, Kharagpur
9	Singapore	Nanyang Technological University
10	Taiwan of China	Taiwan University of Science and Technology
11	Japan	Science University of Tokyo
12	Hong Kong	Hong Kong Polytechnic University
13	Japan	Nagoya Institute of Technology
14	India	University of Roorkee
15	China	University of Science and Technology of China
16	Japan	Muroran Institute of Technology
17	China	Beijing University of Posts and Communications
18	China	Huazhong University of Science and Technology
19	India	Birla Institute of Technology and Science
20	Pakistan	National University of Sciences and Technology

Note: Universities were assessed by *Asiaweek* magazine according to five criteria: academic reputation, student selectivity, faculty resources, research and financial resources. *Asiaweek* discontinued publication after 2000.

Source: *Asiaweek*: http://www.asiaweek.com/asiaweek/features/universities2000/index.html

various biotechnology-based programmes in agriculture, medical, environment and other related areas which, in budgetary terms, double the amount invested in S&T via the DBT. In the past five years, the most significant development in the biotechnology sector has been the evolution of three main high-technology knowledge-based ‘biotech clusters’, in Bangalore, Hyderabad (known as Genome Valley) and Delhi. Here, public–private partnerships have given rise to biotechnology venture funds to develop these clusters. India’s major universities and government-supported laboratories are located in these cities, all of which have initiated long-term R&D programmes in all fields of biotechnology.

The development of biotechnology clusters reflects a ‘Triple Helix’, that is, a tripartite partnership between government, university and industry, in this case to foster innovation in biotechnology and thereby advance both scientific and social goals. Whereas D. Balasubramanian, India’s leading biologist, characterizes Hyderabad as ‘the hub of biotechnology activity’ (*Asia-Pacific Biotech News*, 21 February 2000), the founder CEO of Biocon Inc. in Bangalore, Kiran Mazumdar-Shaw, underlines the fact that ‘the combination of Karnataka’s entrepreneurship and the Andhra government’s vision, strategic direction and support give India a very strong profile’ in biotechnology (*BioSpectrum*, December 2003). (Karnataka is a state of southern India.)

India’s biotechnology market is estimated to be worth around US$ 2.5 billion currently and could quadruple by 2010, creating one million jobs in the process. According to one estimate, there were about 25 000 biotech workers in India in 2005 (*Yahoo! India News*, 11 July 2005). The DBT-supported Biotechnology Consortium of India (BCI) groups 176 biotechnology firms, 49% of which are active in agriculture, 25% in health and 26% in environmental biotechnology; this qualifies the Indian biotechnology sector as one of the most prominent in the Asia–Pacific region, together with those of Australia and China/Hong Kong (Ernst & Young, 2004). India’s biotechnology industry is however not confined to the market end of the S&T spectrum: it is also strongly oriented by health and welfare needs.

India's new patent ordinance

The new ordinance amending the Indian Patents Act of 1970 came into effect on 1 January 2005. India now conforms to the Trade-Related Intellectual Property Rights (TRIPS) Agreement of the World Trade Organization (WTO). India's previous Patent Act had not allowed product patents in drugs, food and chemicals but only process patents in these fields for up to seven years. The most significant changes brought about by the new ordinance are as follows:

- It extends product patents for all fields of technology, including medicine, food and chemicals, offering 20 years' protection. The ordinance eliminates exclusive marketing rights (EMRs), which were providing patent-like protection without the grant of patents. It also allows for the patenting of software that has a technical application; thus, embedded software can now be patented.
- It provides that 'mere new use' for a known substance cannot be patented.
- It also strengthens patent opposition proceedings by allowing for both pre-grant and post-grant opposition. The processing time limits for examination of patents have also been reduced from 48 months to 36 months.
- It has a provision for granting compulsory licences for export of medicines to countries that have insufficient or no manufacturing capacity, to meet emergent public health situations (in accordance with the Doha Declaration on TRIPS and Public Health). This means that Indian companies will be able to produce and export AIDS drugs to African and South-East Asian countries.
- Another modification is the introduction of a provision making patent rights for mailbox applications available only from the date of granting the patent and not retrospectively from the date of publication. This will save many Indian companies from being attacked for infringement of patent law by multinational companies which might otherwise have obtained patents for drugs that Indian companies had already put on the market.
- There is also concern that domestic pharmaceutical and agricultural sectors will be affected, as the new ordinance will make it possible for multinational corporations (MNCs) to dominate the Indian economy. However, 97% of all drugs manufactured in India are off-patent and so will remain unaffected. These include all life-saving drugs, as well as medicines for daily use to treat common aliments.
- The ordinance also has a provision for outright acquisition of the patent to meet national requirements.

The ordinance will encourage Indian pharmaceutical companies to emphasize R&D-based innovative growth. The Indian pharmaceutical and biotech industry offers huge scope for the outsourcing of research. Now with the right legal framework in place for the protection of the results of that research, India could become a global research hub.

Source:
http://iplg.com/resources/articles/india_new_patent_ordinance.html

Much of the impact of India's recent efforts in biotechnology can be seen in the medical sphere. Indian biotechnology attracted global attention recently when a group of public science institutions which included CSIR laboratories and private firms (Shanta Biotechnics in Hyderabad, Bharat Biotech and the Serum Institute of India) developed three vaccines for hepatitis B in 2000–01 to bring down the price of the imported vaccine from US$ 16 per dose to US$ 0.50 in India (Kumar *et al.*, 2004). This followed the commercialization of an anti-leprosy vaccine in 1997–98.

The strength of the Indian biotechnology programme in the area of health has been quite remarkable. Eight other vaccines are currently under development and at various stages of clinical trials. These vaccines target cholera, fertility in humans and animals, rota-viral diarrhoea, Japanese encephalitis, rabies, tuberculosis, malaria and, most significantly, HIV AIDS. These vaccines are likely to be commercialized by 2006–07, according to the DBT in New Delhi.

Other successful examples of the biotechnology programme for health are the development by private firms of recombinant therapeutics for anaemia, diabetes, visceral leishamaniasis, cancer and cardiovascular diseases. In the area of diagnostics, kits have been developed for HIV-1, HIV-2, hepatitis C and neurocysticercosis.

Pakistan

Much of R&D in Pakistan is undertaken by the country's 37 public universities and 110 research institutes. GERD is invested mostly by the government, the private sector playing only a residual role. In Pakistan, S&T has witnessed unprecedented support from government in the form of growing R&D budgets since President Musharraf took the reins in 2000. S&T has been legitimized primarily through the recommendations of the National Commission for Science and Technology, organized in May 2000 under the executive authority of the President. This commission by and large endorsed the priorities for S&T laid down earlier in the country's Ninth Five-Year Plan covering 1998–2003 (Naim, 2005). For instance, between 1999 and 2004, while overall S&T expenditure climbed from 0.28% to 0.51% of GDP, GERD more than doubled, from 0.11% to 0.24% of GDP. The most notable increase was in R&D expenditure on higher education, which grew nearly fourfold from around 530 to 2 000 million Rupees (PKR).[2] In this connection, it is interesting to note that Pakistan's National University for Science and Technology figured in the top 20 Asian universities in 2000 (Table 3).

As Table 5 shows, support since the arrival of the new regime has focused on four areas: agriculture, health, engineering and defence and industrial research. Even though Pakistan's support for R&D and higher education has improved considerably in the past five years, it still has one of the lowest ratios of scientists and engineers (69) per million inhabitants, after Bangladesh (51) and Nepal (40) (Table 2). Even though these figures relate to 2000, the situation remains unchanged in 2005. It is for this reason that the government has accorded top priority to higher education, as revealed by the recent budget increase and by the initiation of four major programmes by the Ministry of Science and Technology in 2001 to increase enrolment in the full spectrum of scientific disciplines from 60 to 700

Table 4
CENTRES OF EXCELLENCE IN PAKISTAN, 2004
By field

Subject	University
Analytical chemistry	Sindh
Mineralogy	Balochistan
Geology	Peshawar
Marine biology	Karachi
Solid-state physics	Punjab
Water resource engineering	Engineering and Technology
Psychology	Quaid-I-Azam
Physical chemistry	Peshawar
Advanced molecular biology	Punjab

Source: Pakistan Council for Science and Technology (PCST).

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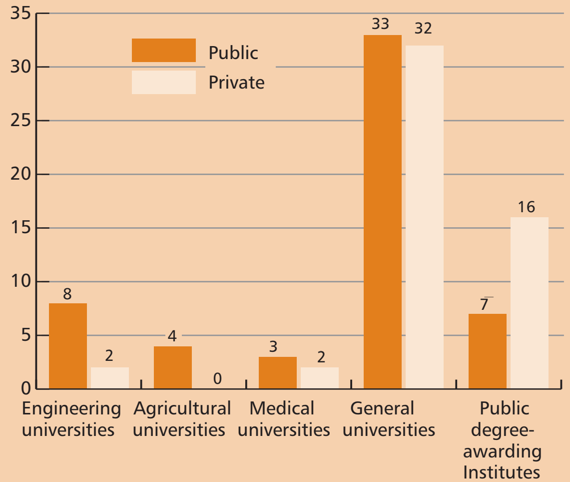
[2] 59 Pakistan Rupees (PKR) were equivalent to US$1 in June 2005.

Figure 6
UNIVERSITIES AND DEGREE-AWARDING INSTITUTES IN PAKISTAN, 2004
By broad field

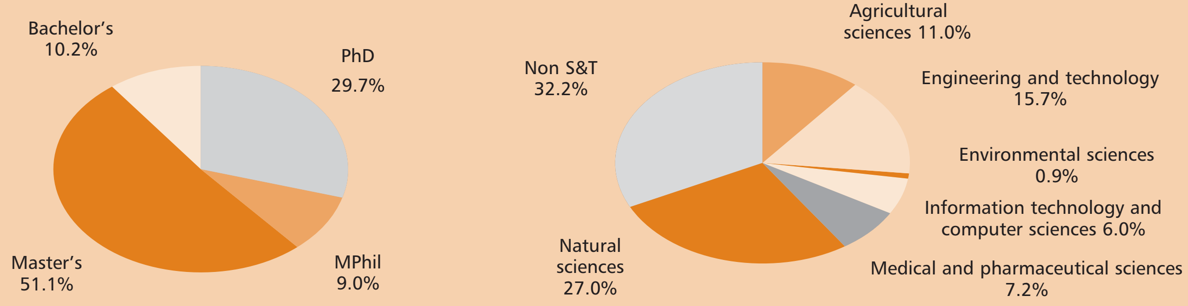


Source: Higher Education Commission 2004 http//www.hec.gov/htmls/hei/collunilist.htm as given by PCST.

PhD candidates per year. Another sign of the priority accorded higher education can be seen in the growth in the number of universities, particularly private universities, from 33 in 1997 to 107 in 2004 (Naim, 2005).

Apart from higher education, the major focus of the government's S&T policy in the past five years has been centred on three main fields: biotechnology, IT and engineering. In the field of modern biological sciences, two national laboratories have been set up in the past few years, the National Institute of Biotechnology and Genetic Engineering (NIBGE) and the Biomedical and Genetic Engineering Laboratories (BGEL). These join the existing Centre for Advanced Molecular Biology at the University of Punjab, dating back to 1981 (Table 4). The NIBGE has accomplished the major achievement of finding a solution via biotechnology for eliminating cotton leaf-curl virus, which plagued the cotton industry. The NIBGE has also successfully used microbes to detoxify

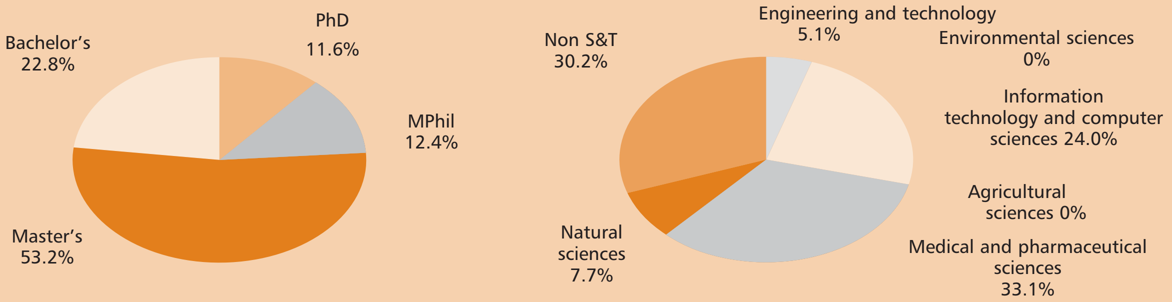
Figure 7
HUMAN RESOURCES IN S&T IN PAKISTAN, 2004


Public sector: level of degree

Public sector: age cohort

Private sector: level of degree

Private sector: age cohort



Source: Higher Education Commission 2004: http//www.hec.gov/htmls/hei/collunilist.htm and PCST, Islamabad, Pakistan.

Table 5
GERD IN PAKISTAN BY FIELD, 1998 AND 2001
In millions of rupees

Field	1998	2001
Agriculture, Livestock and Fisheries	1 368.44	1 766.81
Health	113.04	126.26
Engineering and Technology	77.18	185.49
Industrial Research	244.14	531.76
Forestry	52.94	58.31
Telecommunications	21.29	21.50
Housing and Works	83.51	26.45
Earth Sciences	28.88	39.45
Energy	38.81	41.36
Irrigation and Water Resources	28.75	27.78
S&T Services	10.20	22.20
Science Promotion	11.75	17.27
S&T Policy	6.31	36.50
Defence	95.47	161.27
Transport and Communications	11.09	14.73
Meteorological Sciences	3.93	4.37
Ocean Resources and Marine Sciences	12.23	13.75
Total	**2 207.97**	**3 095.23**

Source: PCST.

effluent and manage waste and to tackle problems related to dyes and chemicals. For its part, the BGEL has identified 20 genetic loci responsible for blindness, deafness and other disorders and perfected DNA-based typing of transplantation antigens for organ transplants. The reputation of the BGEL has been further enhanced by the high citation rate of its papers in international journals (Naim, 2005).

Sri Lanka

According to an R&D survey conducted by the National Science Foundation in Colombo, GERD amounted to $US18.1 million, or 0.19% of GDP, in 2000. This figure was no different in either 1996 or 2004, indicating a relative stagnation of the country's R&D effort. The continuing civil war, coupled with the tsunami disaster in December 2004, has prevented Sri Lanka from making any marked progress in S&T over the past five years. Even though Sri Lanka counts an impressive number of scientists by South Asian standards (191 per million inhabitants in 2004, see Table 2), this figure has again remained static since 1996.

The stagnation in R&D budgets is clearly reflected in the hesitation among students to enrol in postgraduate programmes at university. Whereas the number of science postgraduates more than doubled, progressing from 181 to 439, between 1999 and 2003, the field of engineering experienced ups and downs over the same period, including a massive decline in a single year from 313 to 32, in 2002–03 (Table 6). The situation is more contrasted when we examine the number of graduates between 1995 and 2001: growth in science (from 844 to 1 264), engineering (458 to 548) and medicine (442 to 904) but relative stagnation or even decline in the dental, veterinary and agricultural fields.

The main signs of progress in S&T in Sri Lanka over the past five years are the growing numbers of PhD holders working in universities (719) and R&D institutes (180) and the international publications coming out of Sri Lanka. According to the aforementioned National Survey on R&D, the country published 120 papers in all S&T fields in 1994 which had dropped to 87 by 1996 but picked up again to 164 by the year 2000 (Samarajeewa, 2003; Wickremasinghe and Krishna, 2005).

Table 7 lists the leading R&D institutes in Sri Lanka. As this table shows, more than 60% of these 19 institutions are engaged in agriculture and related areas of research. This figure assumes importance when one considers that 42% of Sri Lankan GDP is derived from agriculture. Despite the importance of biotechnology and modern biological sciences for agriculture and medical research, Sri Lanka has not managed to bolster these leading institutions over the past decade. This is reflected both in staffing levels and in the current R&D expenditure of these institutions. The response of a leading Sri Lankan molecular biologist interviewed in 1999 still holds good six years later; he observed that 'the record of postgraduate research degree programmes in local universities appears indeed dismal'.

The overall picture that emerges from the data is that 'Sri Lanka does not possess the critical mass of

Table 6

ENROLMENT OF POSTGRADUATE UNIVERSITY STUDENTS IN SRI LANKA, 1999–2003

Year	**Science**	**Agriculture**	**Engineering**	**Architecture**	**Medicine**	**Dental**	**Veterinary**	**Total**
1999	181	0	115	76	102	2	0	476
2001	286	55	168	0	14	0	0	523
2003	439	41	32	27	43	1	1	584

Source: University Grants Commission (2004) *Sri Lanka University Year Book 2003/2004*. Colombo; National Science Foundation (NSF), Colombo.

bio-science/biotechnology personnel with adequate levels of training to engage in productive R&D activity in biotechnology' (Karunanayake, 1999, p. 306). There are just two or three research groups in modern biology at the University of Colombo and other institutions running postgraduate programmes. The lack of an adequate science and innovation base for this frontier area of biology in half of the leading research institutes is likely to have serious

Table 7

LEADING PUBLIC R&D INSTITUTIONS IN SRI LANKA, 2004

Name of institution	**Scientists/ engineers**	**R&D expenditure (Rs million)***
Horticultural Research & Development Institute	64	0.4
Farm Crops Research & Development Institute	36	34.1
Rice Research & Development Institute	17	23.8
Regional Agricultural Research Centre	13	6.2
Rubber Research Institute	38	100.0
Tea Research Institute	46	154.4
Coconut Research Institute	34	110.0
Sugarcane Research Institute	19	–
Institute of Post Harvest Technology	12	10.2
Hector Kobbekaduwa Agrarian Research Institute	30	48.0
Veterinary Research Institute	29	40.4
National Engineering Research & Development Centre	47	101.7
Arthur C. Clarke Institute of Modern Technology	22	13.4
National Building Research Organization	52	12.1
Institute of Fundamental Studies	31	40.2
Industrial Technology Institute	67	80.0
Ceramic Research & Development Centre	7	4.6
Medical Research institute	20	2.8
Bandaranaike Memorial Ayrvedic Research Institute	17	44.7
Total	**601**	**827.0**

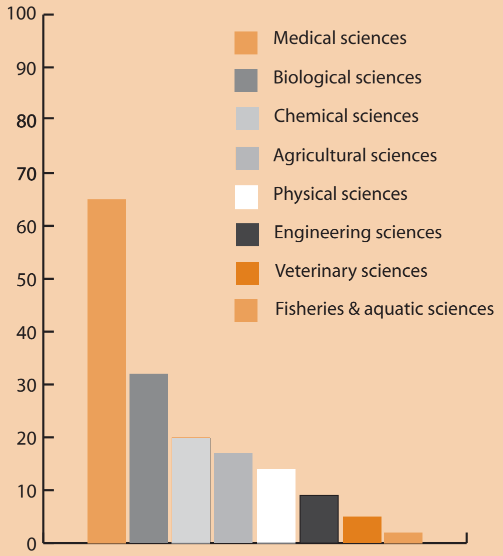
* 100 Sri Lanka Rupees were equivalent to US$1 in June 2005.

Source: NSF, Colombo.

Figure 8

INTERNATIONAL CO-PUBLICATIONS INVOLVING SRI LANKAN AUTHORS, 2000

By subject area, in numbers



Source: National Science Foundation (2000) *National Survey on R&D*. NSF, Colombo repercussions for the relevance of such institutions to the Sri Lankan economy, dependent as it is on plantations and connected industries.

In the area of industrial research, the scene is dominated by the Industrial Technology Institute (ITI, created in 1955 as the Ceylon Institute of Scientific and Industrial Research) and the National Engineering Research and Development Centre (NERDC). In 2004, the ITI and NERDC together employed 124 scientists and engineers. The institute's major problem has been the lack of highly trained scientists with postgraduate degrees. The work of these institutions relates mainly to small industries and quality control, testing and industrial trouble-shooting. It is this latter component, which has grown over the past few years, that is worrying, in that it is driving the ITI and NERDC away from R&D programmes. According to the National Intellectual Property Office of Sri Lanka, the number of patents granted annually to residents between 1995 and 2002 remained stable at about 55–62 on average. A recent study shows that, whereas individual inventors claimed 72% of patents and private institutions 22% in 2000, just 6% went to public institutions. Moreover, the same study demonstrates that the majority of patents were granted for small technologies (Amaradasa and de Silva, 2002).

Bangladesh

The S&T effort of Bangladesh has been quite dismal in the decade to 2004, with a GERD/GDP ratio of just 0.01%. However, some confusion surrounds this figure, the one cited in international data bases and national sources. The official figure is disputed by a leading technology management expert from Bangladesh who puts it at 0.22% in 2005. Much of the country's strength in S&T derives from 21 universities and a handful of leading science agencies, such as the Bangladesh Rice Research Institute (BRRI) and Bangladesh Council for Scientific and Industrial Research (BCSIR).

Among the 21 universities in Bangladesh, 16 are devoted mainly to teaching, the remainder being considered as both teaching and research universities. According to output data available for 11 universities for 2003, there were over 16 000 graduate students from fields that included the natural, engineering and social sciences. Of these, 3 000 had obtained their degree in engineering and medical sciences. There were an estimated 1 368 postgraduates in S&T fields coming out of universities in 2003 (Islam, 2005).

In Bangladesh, the main strength of R&D has been in the 14 leading R&D institutions shown in Table 8. They employ 2 785 scientists and engineers. A consequence of the low level of R&D funding available for public research is that the proportion of PhD holders in the total S&T human resource base has been declining quite rapidly. For instance, the BCSIR employed 7.5% of PhD holders in 1986 but only 3.71% in 2004, a state of affairs only too familiar to other R&D organizations.

Table 8
LEADING PUBLIC R&D INSTITUTIONS IN BANGLADESH, 2003

Name of institution	No of scientists/ engineers	No. of technicians
Bangladesh Agricultural Institute	780	84
Bangladesh Jute Research Institute	280	189
Soil Resources Development Institute	125	19
Bangladesh Tea Research Institute	45	19
Bangladesh Space Research and Remote Sensing Organisation	60	39
Bangladesh Forest Research Institute	125	79
Bangladesh Livestock Research Institute	120	67
Institute of Postgraduate Medicine and Research	280	400
International Centre for Diarrhoeal Research	226	150
Atomic Energy Research Establishment	287	204
Bangladesh Council for Scientific and Industrial Research	345	320
Bangladesh National Scientific Documentation Centre	14	12
Institute for Nuclear Medicine	35	9
River Research Institute	63	80
Total	**2 785**	**1 671**

Source: BANSDOC, Dhaka and from individual institutions.

Among science bodies, the role of the BRRI has been central to Bangladeshi agriculture. The BRRI has developed and released 31 modern varieties of rice in the past two decades. Annual rice production (the main staple food) more than doubled between 1970 and 2002, from 10.8 million metric tonnes to 24.3 million metric tonnes. Without the BRRI's modern varieties, rice production would have increased by just 10% over this period. The contribution of modern rice varieties developed by BRRI has therefore been substantial and today accounts for 65% of total rice production.

The BCSIR is a major civil R&D institute; it patented 280 processes between 1972 and 1995 but could only transfer 40 of these to industry. There is a problem with commercializing technology developed by the BCSIR, caused by a lack of perceived need in industry, a small market size and inadequate upscaling from the point of commercial success. Domestic research efforts have mainly contributed to cottage and small industries. Even here, their implementation suffers from the absence of linkages among research institutions on the one hand and between research institutions and entrepreneurs on the other (Islam and Haque, 1994, p. 208). The BCSIR's work is often confined to trouble-shooting industrial work (Haque and Islam, 1997). There are no long-term R&D programmes and the BCSIR's links with universities are almost non-existent. As the recent study by Islam (2005) shows, these problems still persist in the case of BCSIR and current investment in R&D by the government is hardly sufficient to develop any worthwhile technology-based programmes. The major weakness is reported to be an acute shortage of human resources coupled with the lack of a policy strategy to revamp the R&D sector with an infusion of funds commensurable with the growing demands of industry.

Nepal

In Nepal, there are an estimated 12–15 000 working scientists and engineers but R&D remains a marginal activity (Bajracharya and Bhuju, 2000). S&T has yet to receive the priority it deserves in government policies and programmes. The establishment of a Ministry of Science and Technology in 1996 was cause for lively public debate, with some commentators considering the separate ministry a luxury that Nepal could not afford. The government stood its ground, enabling the Ministry of Science and Technology to join the ranks of the Royal Nepal Academy of Science (RONAST, established in 1982) and the Ministry of Population and Environment (1995).

Other recent institutions are Kathmandu University, the Centre for Renewable Energy, the Nepal Health Research Council and the Agricultural Research Council (all dating from 1991), the Environmental Protection Council (1992), Nepal Engineering College and Manipal College of Medical Sciences (1994), the Kathmandu, Nepal and Nepalgunj Medical Colleges (1997) and, since 1998, Kantipur Engineering College (Bajracharya and Bhuju, 2000). In 1998, RONAST and the Ministry of Science and Technology began preparing a 20-year plan for the development of S&T in Nepal.

The Ninth Plan (1997–2002) recognizes, more than earlier government pronouncements, the importance for the country's S&T effort of new technologies, particularly biotechnology and IT, and of increasing productivity through the application of S&T in various sectors. In 2000, Nepal formulated its Information Technology Policy: 2057, with the main objectives of making IT accessible to people at large and creating employment; building a knowledge-based society; and establishing knowledge-based industries. In a primarily agrarian economy, S&T policies have also stressed the application of biotechnology to agriculture and animal husbandry.

Given the agrarian base, in 2003–04, efforts to articulate national biotechnology policy gained currency. Despite the positive S&T policy discourse at the national level, the country had not witnessed any significant increase in the GERD/GDP ratio in the 1990s. This has all changed in recent years, however, with expenditure at a record high of 0.26% of GDP by 2004 (double the figure in 1985).

This level of R&D funding is much higher than that of 0.01% for Bangladesh.

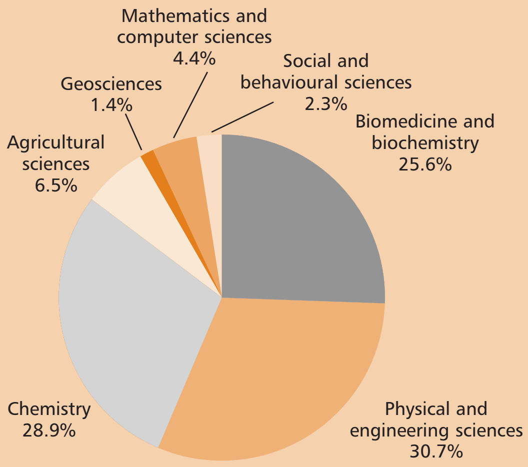
Iran

With oil representing a major source of national wealth in Iran, S&T has only recently been placed high on the agenda for industrial development. The first development plan (1988–93) was a focused attempt to build local S&T infrastructure and implement strategic projects in agriculture and oil industry-related areas. This support for S&T has been pursued in the government's Third Socio-Economic Development Plan 2000–04. One of the major outcomes of this plan is the establishment of a Ministry of Science and Technology.

The GERD/GDP ratio has more than tripled in Iran in recent years, from 0.15% in 1985 to 0.50% in 2002. Much of this has gone on building up local technical capacity and engineering education. The 61 tertiary institutions in the country also incorporate the medical faculties in the main universities. The growing S&T effort in the past decade and particularly in the last Five Year Plan mentioned above has enabled the country to make its presence felt in the international sphere, as depicted in Table 9 and Figure 9. The number of SCI-based publications by Iranian scientists has witnessed a more than threefold increase in just five years, from 400 in 1995 to 1 400 in 2000. More than 80% of these publications are distributed equally among the three broad fields of biomedicine and biochemistry, physical and engineering sciences and chemistry. There are several factors responsible for the notable increase in the number of science publications in recent years: the war's end, better economic conditions, the recent changes in the government's policy for research funding, basic changes in the political environment brought about by the reformers, expansion of the Iranian presses for national journals and the recent return of a large number of students trained overseas on government scholarships. External factors also account for the increased productivity, such as the acceptance of three Iranian source journals by the SCI; greater access to international databases through the Internet; and better electronic communication facilities for international collaboration (Osareh and Wilson, 2002).

Iran has had its ups and downs in terms of scientific endeavour. The main problems hampering the growth of national scientific communities are the lack of recognition of science as a social institution requiring a certain degree of autonomy and a space for critical discourse; the lack of international mobility for scientists; and a sense among scientists

Figure 9
SCIENTIFIC PUBLICATIONS IN IRAN, 1995–99
By field



Source: based on Osareh and Wilson (2002).

Table 9
IRANIAN PUBLICATIONS CITED IN SCI*, 1978–2000

Year	Number of publications
1978	610
1985	180+
1995	400
1998	1000+
2000	1400

*Science Citation Index of Institute of Scientific Information (ISI-Thomson) in Philadelphia, USA.

Source: based on Osareh and Wilson (2002).

of isolation. As one Iranian scientist put it at a recent seminar:

> *'Iran's failure is all the more surprising in view of its vast oil revenues. Given the speed, complexity and ever-increasing costs of modern S&T research in the world, countries like Iran are in danger of getting totally marginalized in the race that will determine the fate of the coming century. ... Iran has never grasped the importance of a modern scientific world view and systemic changes that allow critical and experimental thought to replace – no matter at what cost – submission to higher authority. Great intellectual and political courage is needed to break away from these ancient frames of mind. Iran's problem in any case is not technology transfer but those conditions that prevent the propagation of scientific thought, modern rationality and technology creation.'*
>
> (Mahadavy, 1999, p. 30)

Even though the reforms in Iranian society have been progressing quite rapidly in recent years, Mahadavy's words take on fresh relevance with the election of the new president in June 2005.

Mongolia

The Mongolian science system reflects a structure dominated by government, be it in terms of the pattern of funding or output. In the private sector, the technical capacity is very weak and establishing linkages with science agencies and institutions in the public sector remains a major challenge (Turpin and Bulgaa, 2004). According to a WIPO source, Mongolian residents registered 63 applications for industrial design patents in 2000, which is said to be double that in 1999, indicating the growing strength of the technology system. Some 60 patents were granted in 2000 (WIPO Technical Report, 2000).

From the 1960s to the 1990s, it was the Mongolian Academy of Sciences (MAS), established in 1961, and the National University of Mongolia (1942) which provided a platform for the development of universities in agriculture, medicine, engineering and the humanities. MAS was reformed in 1996 and research institutes and universities were reorganized the same year with the creation of the National Council of Science and Technology (NCST). Two years later, a new state policy on S&T was introduced and a National Science and Technology Fund created.

Mongolia's efforts to foster both S&T and education in the 1990s are bearing fruit. Mongolia could boast 1 370 scientists and engineers per million inhabitants (Table 2) in 2002, a figure which surpasses that of all other South Asian countries. The government devoted Tugrik 3.5 billion[3] to R&D in 1997 (about 0.28% of total government expenditure). Universities are essentially self-financing.

In the past decade, the country has given precedence to education in management and IT by establishing two major institutions, the Computer Science and Management Institute (1991) and the School of Information Technology (1994). These institutions had a combined student roll of 950 in 1998 and employed 146 faculty members. Since emerging from the influence of the former Soviet Union in 1991, Mongolia has moved towards a market economy and economic liberalization. This has had a direct bearing on the S&T system; the government has developed R&D capacities to market new technologies which compete with those of fledgling private firms. The last five years have witnessed significant change in the research environment. The thirst for scientific knowledge is growing as Mongolia struggles to compete in an increasingly knowledge-intensive global economy. The government is conscious of the need to confront these challenges and is consequently turning to international cooperation to strengthen the country's S&T capacities. It is according considerable importance to an unhindered flow of information and to the exchange of experience and expertise on S&T matters. In the past five years, ICTs have been seen as a dynamic sector in Mongolia. Foreign investment, technical assistance and cooperation with technically advanced nations in ICT development have all grown. It is noteworthy that the prime minister himself

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[3] 1,120 Mongolian Tugrik (MNT) were equivalent to US$ 1 in June 2005.

heads the National ICT Committee. A national ICT Vision – 2010 lays out the government's principal strategies for ICT development.

CIVIL VERSUS MILITARY R&D EXPENDITURE

When adjusted for inflation, the GERD/GDP ratio over the past decade has either stagnated or declined for the countries of the region, with the notable exception of Nepal. Although India spends much more on R&D than other South Asian countries, it witnessed only a small increase from 0.83% to 1.08% between 1997 and 2004; moreover, this masks negative growth once the figures are adjusted for inflation. If, in absolute terms, GERD has increased in India, it has not kept pace with rising GNP figures. India has set itself the target of devoting 2% of GDP to R&D by 2007. The target was first unveiled in *Science and Technology Policy 2003* by then Prime Minister Atal Bihari Vaijapee and has since been endorsed by current Prime Minister Dr Manmohan Singh.

The proportion of Indian R&D expenditure devoted to civilian R&D hovers between 50% and 60% of the total, with the rest consumed by the defence and strategic sector R&D agencies (atomic energy, defence and space research). Research into non-conventional energy sources has been one of the casualties of strong growth in the atomic energy research budget. In the absence of any significant spin-offs for the civilian sector (except in the case of space research) and in light of the relative decrease in the S&T budget in the 1990s over earlier years – a decrease which did not adversely affect the defence and strategic sector – policy planners are now mobilizing private industry's support for R&D in 2003–04. The private sector performs 23% of R&D in India. This is low by Asian standards, the average for the Newly Industrialized Asian economies being close to 72%. The Indian figure is more comparable with that for Brazil (37%) (OST, 2004).

The situation is even more alarming for the civilian sectors of R&D in Pakistan, which spends just 0.24% of GDP on R&D as a whole (Figure 1). Whereas military expenditure as a percentage of GDP dropped for India from 3.0% to 2.4% between 1985 and 2000–04, the relative decrease for Pakistan's military expenditure was from 6.9% in 1985 to 3.9% for 2000–04. With the peace initiatives gaining momentum in both countries in the past five years, the military burden is likely to further come down in the coming years, which will enable these countries to invest more in education and science and technology. The military burden can be seen in other countries too. Whereas Bangladesh and Nepal are spending around 1.5% of their GDP on military expenditure, Sri Lanka devotes just 0.27% of GDP to this purpose. In the case of Iran, although military expenditure dropped by a third (from 3.6% to 2.7% of GDP) between 1985 and 1996, it climbed back to 3.3% in 2004. It is important to note that the heavy military burden in South Asia has prevented many countries in the region from devoting the resources to R&D and S&T that they deserve.

STATUS OF NATIONAL SCIENTIFIC COMMUNITIES

With low levels of R&D expenditure over the decade, South Asian countries are still struggling to establish infrastructure in S&T and higher education. As this process has become more and more capital-intensive, the long neglect of S&T has led to serious crises both in the institutionalization of S&T domains and in the professionalization of national scientific communities. The concept of scientific communities does not encompass mere numbers, infrastructure and money. Although these elements are essential, it takes time to establish highly professional and effective scientific communities in specialized fields of research. Some basic indicators refer to a steady production of basic and applied S&T knowledge in specialized fields of research; constitution of new disciplines, specialties and areas of research; university chairs and postgraduate programmes; systems of national recognition and rewards; full-time specialized research institutes in critical areas of national importance; networks of S&T research and national communication patterns with corresponding journals and professional academies, bodies and so on; social and political legitimacy for science with steady state support in the initial stages; and above all the existence of an intellectual climate where individual scientists within national boundaries do not experience a sense of isolation.

If endogenous capacities in S&T, including agriculture, are to be created in the countries of South Asia, there is no shortcut to establishing national scientific communities in the sociological sense of the term (Gaillard, Krisha and Waast, 1997). Oriented basic research, scientific communities and PhD programmes in universities are interlinked complementarities and should be considered as crucial elements for generating local technical capacities. This is because what is known as 'codified knowledge' (such as published papers, patents or copyright designs) can be transferred from one place to another but very often the essential component of 'tacit knowledge', which is embodied in a person and mastered through a lengthy process of 'learning by doing' cannot easily be transferred (Krishna, Waast and Gaillard, 1998).

PhD training at universities and research laboratories in S&T is the main source of tacit knowledge. In varying forms, this knowledge is also interlinked with the 'core competencies' of institutions and organizations which evolve through time and effort, and which cannot easily be traded and transplanted from one place to another. With the increasing importance of intellectual property regimes and globalization, conventional forms of technology transfer are unlikely to persist into the future. Even if they do, they will prove to be much more expensive than creating local, national capacities with a long-term perspective. In agricultural and biological sciences, both of critical importance for agrarian South Asian countries, the status of national scientific communities will determine the strengths of local technological capacities in generating wealth from knowledge. This holds true even for the expanding manufacturing and services sectors, which in the last decade have become more and more knowledge-intensive and interdisciplinary.

Creating a national base in science has indeed become crucial to developing countries where the transnational corporations (TNCs) have set off a competitive race to lay claim to specific biological knowledge. World sales of modern medicines derived from plants discovered by indigenous people in developing countries are estimated at US$ 43 billion (World Bank, 1999, p. 146). Biodiversity is of great economic value to drug development and pharmaceutical TNCs and it is estimated that developing countries are the major source (about 90%) of the world store of biological resources. The USA-based multinational, Eli Lilly, made US$ 100 million by developing anti-cancer drugs from the rosy periwinkle found in Madagascar. The country is reported to have received nothing from this economic gain (UNDP, 1999, p. 70).

Developing countries can only benefit from their biodiversity and the rare germplasm found in their land provided they develop, protect (through intellectual property regimes) and apply modern biological knowledge. At the same time, appropriate policy provisions must be made to protect the interests of the indigenous communities in developing countries who are the cultivators and protectors of plants, as well as the repositories of knowledge about plant-based remedies accumulated over generations. Without an endogenous base in S&T, no country can take advantage of its rightful resources. South Asian countries, with the exception of India, are still in the process of institutionalizing S&T systems. With the low level of government support for science, there are serious crises in the training and promotion of research in new fields such as micro-electronics, biotechnology and molecular biology and ICTs.

There are severe problems involved in the constitution and growth of scientific communities across crucial areas of research in Bhutan, Iran, Myanmar, Bangladesh, Sri Lanka, Nepal and Pakistan. It should however be noted that the status of national scientific communities as a factor of socio-economic development varies quite remarkably between small countries like Bhutan, the Maldives and Mongolia and the rest of South Asia. Although it is difficult to speak of developed national scientific communities, there are specialist groups and communities in some sectors: agriculture in Bangladesh, Myanmar, Nepal and Sri Lanka; and physical and chemical sciences in Iran and

Pakistan. India has well-developed S&T systems and national scientific communities. Having gone through a first phase of initial professionalization, India's problem lies in its 'second order' professionalization; this consists of forging linkages with industrial and societal sectors on the one hand and developing technological capability to compete at the global level on the other.

SOCIAL ORGANIZATION OF SCIENTISTS

One problem underlying the constitution and growth of scientific communities in South Asia relates to the professional climate and social organization of scientists in R&D institutions and universities, coupled with brain drain. A sense of isolation prevails among scientists in the absence of relevant professional groups of researchers, scientific elites and frequent professional meetings. There are national science academies in each country but their activities are generally confined to holding annual meetings. There are few activities among professional bodies to catalyse the intellectual atmosphere. Lack of peer evaluation systems for the advancement of scientific careers in laboratories and publication in journals is a serious problem cited by scientists in Bangladesh, India, Iran and Sri Lanka. For instance, scientists in Bangladesh are evaluated on the basis of a colonial system of confidential reporting and the seniority principle applies rather than an open merit-based system. Further, according to scientists interviewed, as senior-level positions in the laboratories are limited to around 10–20% of the total, there is hardly any motivation to do creative research.

In a South Asian research system dominated by government funding, there are several bureaucratic problems relating to the organization and pursuit of scientific research. For instance, as a leading Indian scientist observes, 'for research funding to be truly efficacious, you have to have the best people, best material infrastructure and minimal bureaucracy. These three components are not optimal and hence research output is not proportionate to the funding' (Ratnasamy, 1999). Given the continuing bureaucratic problems in Indian science, it is not surprising that the prime minister reiterated his government's commitment to de-bureaucratize S&T institutions while addressing a meeting of the Indian Science Congress on 3 January 2005.

Closely related is the major issue of strengthening scientific excellence and academic standards, attracting the best teachers in S&T disciplines and promoting basic research and professionalization of science in academia. Another serious problem not confined to South Asian countries is the problem of attracting the best students to science at the undergraduate and postgraduate levels. Serious concerns in relation to these issues are recurrently being debated in India (Rao, 1999; Krishna, 2001; Lakhotia, 2005). This said, such problems are of a much more severe nature in South Asian countries. Whereas most developed countries are spending 25–30% of their total R&D budget in the university sector, the South Asian average is estimated to be less than 8–10%.

Since the early 1990s, liberalization and privatization policies have led to enormous salary differences between government and private agencies, further impoverishing the material conditions of scientists. Whereas the salary levels for public researchers in South Asia have witnessed only a moderate increase (the current average ranges from US$ 250 to US$ 600 per month equivalent), the salary package in the private sector (for engineers and technologists, software professionals and business executive classes) has increased four- or fivefold. For instance, in the 'silicon valley' of India (Bangalore), in MNCs and private firms, middle-level executives, scientists, engineers and management professionals earn as much as their counterparts in Europe and the USA. This is driving away the best talent from public-funded research institutions and university positions. From an overall perspective, as a Sri Lankan biologist observed, 'once the needed scientific infrastructure is strongly laid and the basics of comfortable living for these scientists are sorted out, their intellectual capacity and innovative ideas can be developed into products of human consumption and utility and also of commercial value' (Karunanayake, 1999, p. 310). Further, as Lakhotia (2005) rightly observes, 'a teaching job at a college or a university is not preferred by brighter PhDs. Many happen to be teaching in colleges or universities because they could not find other jobs.'

BRAIN DRAIN

A sense of isolation, lack of incentives and poor motivation to do research, combined with a low pay structure in laboratories, have led to both internal and external brain drain in South Asia. Internal brain drain in a limited way refers to loss of core competencies due to a critical mass of professionals leaving the public institutions within a country for private employers. It also refers to engineers, doctors and professionals trained in S&T opting for management and administrative positions offering better pay and working conditions. India is a good example for both of these reference points as publicly funded R&D agencies have experienced a good deal of internal brain drain in the past five years: over 70% of the best Indian engineers from the Indian Institutes of Technology (IITs, see also box) prefer management and marketing positions to 'hard core' engineering professions (Krishna and Khadria, 1997; Khadria, 1999). Similar trends are to be observed in Bangladesh, Iran, Nepal, Pakistan and Sri Lanka.

External brain drain refers to emigrating professionals whose departure causes potential loss to the economy. The USA is the most favoured destination: estimates of South Asian migration to the USA till 2003 are of 1 million of which 20% were Indian and 20% were from other Asian countries. Even if we assume that only 20% of this (non-Indian) Asian figure covers South Asia – including Iran where there is a 90% state subsidy for higher education – one can imagine the loss incurred by these countries. For instance, according to the Overseas Employment Corporation in Pakistan, 36 000 professionals, including doctors, engineers and teachers, have migrated to other countries over the past three decades (Human Development Centre, 1998, p. 43). India has become the world's major exporter of doctors to the USA. There were 38 000 Indian doctors in the USA in 2004. It is estimated that there is one Indian doctor in the USA for every 1 325 Americans, compared with one Indian doctor in India for every 2 400 Indians. Studies in India have shown that, on average, 25–30% of engineers from the world-class IITs and as many as 56% of medical graduates from the All India Institute of Medical Sciences (AIIMS) migrate, mostly to the USA (Khadria, 1999, p. 112).

When we examine the problem of brain drain in the larger context of Asia, taking examples from countries such as the Republic of Korea and China, we see that these countries have turned the problem of brain drain into brain gain on an immense scale by attracting their scientists back home through various national policies and institutional mechanisms (see also the chapter on East Asia). To tap the knowledge frontiers in the industrially advanced nations, these countries have adopted conscious policies to export professionals in large numbers – even to the point of opening R&D institutional units in the USA. At the same time, they have promoted the professionalization of science and improved the social organization of scientists both to make the research climate attractive to potential returnees and to arrest potential migration.

India has adopted similar professional mechanisms in the area of biotechnology since the government established the Department of Biotechnology (DBT) in the early 1980s. Over the last two decades, the DBT has catalysed the growth of the biotechnology community in India by promoting 40 advanced research and higher training departments in universities and establishing four top-ranking modern biological laboratories. A source on NASSCOM indicates that in the past three years about 25 000 IT-related professionals have returned to India and about 200 start-up companies in IT have been established by returnees. In any case, India is in a somewhat better position now to absorb the temporary shocks generated by professional brain drain but it is indeed a serious problem and a strategic issue for S&T policy in small South Asian countries.

THE NEIGHBOURHOOD EFFECT

A subject of considerable importance and concern in the South Asian context is the ‘neighbourhood effect’ science, technology and higher educational (STE) institutions are having on the transformation of rural society and industry through knowledge and innovation. The forces of modernization and S&T-based industrialization have so far benefited the needs of the urban population. Traditional technology and skills which dominate the rural industrial sector in terms of small and medium-scale enterprises (SMEs) and industrial clusters, concentrated around the districts, have been largely neglected by STE institutions. This is of great concern in India in particular, which accounts for approximately 65% of the region’s population. It is estimated that there are 2 000 small industrial clusters and 300 large consolidated clusters in India, most of which are based on traditional and low technologies. The focus here is on industrial districts and the extent to which the STE institutions located in their immediate neighbourhood could participate in their transformation.

In Meerut, for example, neither its university nor its 20-odd colleges and institutes have any relevant courses on publishing and printing, nor any specialized training related to the design and production of sports goods which could cater to the local industrial clusters in these fields. Similarly, in Agra, the local university and 40 colleges and research institutions have very little to do with training and research programmes concerned with shoe manufacturing or the city’s industrial pollution. Although one of India’s best engineering institutes (an Indian Institute of Technology) is located in Kanpur, the immediate neighbourhood effect is minimal for the leather industrial clusters in the district. The rate at which the pace of global connectivity of research institutions is increasing seems to be inversely proportional to their immediate neighbourhood concerns.

With 300 universities and more than 1 100 research institutions spread over the country in close proximity to industrial clusters, STE institutions can play a crucial role in the rural innovation system. Unlike earlier concerns relating to the development of small-scale industries and manufacturing schemes, this perspective of the neighbourhood effect of STE institutions draws attention to the importance of building new knowledge networks and regional innovation systems that incorporate the concepts of ‘flexible specialization’ in technology and ‘technology blending’ (Bhalla, 1996) at the level of industrial districts.

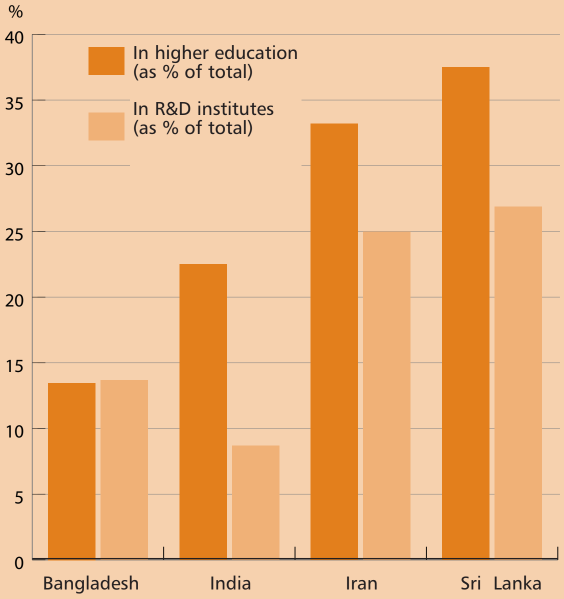
NGO institutions such as Barefoot College in Tilonia, M. S. Swaminathan Foundation in Chennai, the Centre for Technology Development and Development Alternatives in New Delhi, Gonoshasthaya Kendra – The People’s Health Centre in Dhaka, CAPART – Public Institution in New Delhi, SEWA, the Honey Bee Network, and the National Innovation Foundation in Ahmedabad are success stories involved in rural innovation and development. However, universities and S&T institutions – the main sources of new knowledge – can take a lead role in partnerships with district-level governments and civil society towards formulating S&T-based solutions and perspectives in aiding industrial clusters to confront the economic and skill challenges posed by the forces of globalization. There is a need to revamp the policies of small industries to turn these into regional innovation systems without losing sight of the local-traditional production systems. The discussion here emanates from the Indian experience but is also highly relevant to other developing countries.

THE GENDER SITUATION

S&T has led to economic growth and material wealth in general but as Hill (2004) points out in the Asian and Pacific context, ‘the impact of S&T on society has not been achieved for gender equity. Cultural attitudes and gender stereotyping are impediments to education leading to more men than women in S&T careers and in decision-making positions with increasing inequity and inequality.’

In South Asia women constitute 26.6% of the total S&T student population in higher education but only 18.6% of researchers in R&D organizations (Figure 10). In the case of India, whereas the representation of women in higher education (22.5%) is closer to the South Asian average, the proportion of women in the workforce (8.7%) is much lower than the South Asian average. Interestingly, the situation of women in

Figure 10
WOMEN IN HIGHER EDUCATION AND R&D INSTITUTES IN SOUTH ASIA, LATE 1990s
Selected countries (%)



Source: Institute for Research and Planning in Higher Education, Tehran; DST (1999) *R&D Statistics*, New Delhi; BANSDOC (1997) *Survey of R&D Activities in Bangladesh*. Dhaka; NARESA (1998) *National Survey of R&D in Sri Lanka.* Colombo.

Iran and Sri Lanka is comparable to that of women in the USA, where they represent 38% of total graduate enrolment and 22% of the science and engineering workforce (NSF, 1998, p. 2–22). The proportion of women in S&T higher education in the Asia/Pacific region more than doubled from some 15% to 33% between 1970 and 1990 (Harding and McGregor, 1996, p. 312). In South Asia, this progress may be attributed to the remarkable improvements in female literacy between 1970 and 1995. It is also interesting to note the gradual closing of the gender gap in primary enrolment: 35 percentage points for the South Asian region in 1960 compared to 23 percentage points some 30 years later (Human Development Centre, 1998, p. 86–7). The low status of women in South Asian society relates to patriarchal systems and values with deep historical roots. Added to this is the factor of widespread poverty, still a major constraint in tackling the problems of female literacy and education. Patriarchal values pose a different set of problems for women scientists who enter the workforce.

By 2002, most South Asian countries had instituted varying institutional research programmes and mechanisms to promote women in the science, technology and higher education sectors. In India, the Department of Science and Technology instituted two studies (DST, 1992, 1998) on women scientists and engineers, which together surveyed more than 3 500 respondents spread over different parts of India. These studies have shown different notions of 'inequality' in terms of rewards, recognition, participation in decision making and other aspects referred to earlier by Hill (2004). Recognizing the notion of 'inequality in science', the Indian DST has been running a scheme called S&T for Women since 1981 and in the 1990s created special awards and incentive schemes to encourage women scientists. Similarly Nepal, Mongolia and Sri Lanka have taken some institutional measures in their respective ministries to promote women in science and education.

At the regional level, international agencies such as the ILO, UNDP and UNESCO have initiated various action plans and launched concrete projects following the 1995 Beijing Conference. One such programme involving India, Nepal and Mongolia is the Asian-Pacific Gender Equity Network (APGEN), set up by UNESCO's regional bureau for science in Jakarta, Indonesia. The areas and projects promoted by APGEN over the past five years include biotechnology and green health, renewable energy, water and sanitation, and IT. APGEN has been undertaking policy and social analysis research at three levels: gender equity in S&T; the provision of technical assistance to pilot projects in the region; and the dissemination of results and lessons of experience obtained through research and field experience across the region.

SAARC AND REGIONAL COOPERATION IN S&T

In terms of regional cooperation, the South Asian countries – including Iran – are more a geographical entity than an economic bloc along the lines of the European Union or the Association of South-East Asian Nations (ASEAN). The South Asian Association of Regional Cooperation (SAARC), which has seven members (Bangladesh, Bhutan, India, the Maldives, Nepal, Pakistan and Sri Lanka) and dates back to 1985, accounts for 22% of the world population but only 1.65% of world GDP and 1.12% of global trade. Even including Afghanistan, Iran, Mongolia and Myanmar in the equation does not change this economic reality to any large measure.

What is more glaring is the fact that, despite the existence of SAARC for more than 15 years, there is hardly any significant intra-SAARC trade: it represented only 4.25% of total SAARC exports in 1996 and declined to 4% in 2003–04. Furthermore, the main trading partners are Europe and the USA, whose share of SAARC exports increased modestly from 46% in 1990 to 49% in 1996, compared with about 22% for Asian countries, with the exception of Japan. Over the same period, SAARC imports from Europe and the USA rose more steeply, from 53% to 65% (RIS, 1999). This trend continued even in the 2000–04 period. The existing South Asian Preferential Trading Arrangement (SAPTA), which was to catalyse South Asian free trade, has yet to show any noticeable results, indicating a shift away from the present trend.

Another important development in recent years has been the emergence of two sub-regional cooperation groupings. The first consists of Bangladesh, Bhutan, India and Nepal, which have come together to form a Growth Quadrangle called BBIN-GQ. The main objective of this formation is to create a climate for rapid development through the implementation of cooperation projects in communications, transport, energy and natural resource management on a regional basis. The second important sub-regional formation is the initiative taken by Thailand in 1994 to establish Bangladesh–India–Sri Lanka–Thailand Economic Cooperation (BIST-EC). In 1997, Myanmar was admitted to this grouping and it was renamed as BIMST-EC, which paved the way for linking up South Asia with ASEAN economies. Notwithstanding the slow economic start by various groupings and network committees, considerable optimism has been exhibited by various SAARC meetings in recent years.

The major challenge for South Asian countries is thus to enhance their economic and trade ties. Here, regional cooperation should be deemed much more important than that with other partners in so far as various products traded by Asian countries are affected. For instance, economists estimate that Sri Lanka lost approximately US$ 266 million (36% of the actual import bill) and that Pakistan lost US$ 511 million (28% of the actual import bill) in 1994 by not importing goods from SAARC (RIS, 1999). The region's vertically integrated networks in technology, division of labour, production, trade and exports provide enormous scope for the expanding manufacturing and services sector within SAARC. With the Indian information technology sector emerging as an important global player with considerable human capital, there is tremendous potential for cooperation in this high-technology area.

One of the main objectives of regional cooperation as laid down in SAARC's charter is 'to promote active collaboration and mutual assistance in the economic, social, cultural, technical and scientific fields'. It was envisaged that cooperation, over time, would significantly strengthen the region's collective self-reliance. In 1982, through its Technical Committee on Science and Technology (TCST), SAARC identified 14 areas for cooperation ranging from science policy to information. Since 1983, 15 meetings of the TCST have taken place, resulting in a directory of S&T activities in the region; 26 seminars, expert group meetings and workshops; seven training courses; and feasibility studies for the development of specific sectors of cooperation. The other outcome of TCST meetings has been a proposal to create the SAARC Biotechnology Council for developing biotechnology and bioresource policies and to formulate joint technology development programmes, including the establishment of a consultative committee on intellectual property regimes (RIS, 1999).

The 12th SAARC Summit held in Islamabad from 4 to 6 January 2004 reaffirmed that:

> *'strengthening of scientific and technological co-operation across the region is fundamental to accelerating the pace of*

economic and social development. Sharing of scientific and technological expertise, joint research and development and industrial application of higher technology should be encouraged and facilitated.'

Very low or insignificant intra-SAARC trade is by and large reflected in the levels of S&T cooperation within SAARC, in the sense that no long-term R&D programmes with real partnerships have evolved so far. With the easing of tension between India and Pakistan in the last few years, the S&T sub-committee component of SAARC could play a major part in fostering the mobility of professionals through exchange programmes in universities. Being a large country, India could take a lead in the form of SAARC fellowship programmes for greater exchange of students between India and other South Asian countries in areas where India has developed high-class research infrastructure in space, ICT, agriculture, chemical and drugs among other areas of science including S&T policies.

CONCLUDING REMARKS

The triple challenges facing all South Asian countries are:

- agriculture and health security coupled with tackling the problems of poverty and unemployment among growing population;
- coping with the rapid transformations underway due to scientific and technological revolutions unleashed by the developments in ICT, biotechnologies and other fields;
- managing the transition from agriculture-based economies to industrial and knowledge-based service economies, addressing the issue of good governance.

In our view, the three basic elements of a response agenda to the prevailing challenges in S&T, including the educational implications, are:

- expansion of educational opportunities at all levels, particularly the primary and middle levels, looking to reach a sustained level of education expenditure around 5–6% of GDP;
- an increase in government or national expenditure on R&D to a minimum level of 1% of GDP and expenditure on S&T activities to at least 2–3% of GDP, with a focus on creating employment in small- and medium-scale enterprises;
- concrete steps in tackling corruption, decentralization of developmental processes and giving effect to good governance.

Unfortunately, most countries have failed to pay adequate attention to these challenges in their policies during the last decade. With the exception of India, most countries in the region are spending an average of less than 0.5% of GDP on R&D. The major achievement during this period has been in the area of agricultural research, which has contributed to agricultural productivity and hence provided food security in many countries of the region. However, with a 2% average population growth rate, the ongoing task confronting the agricultural scientific communities is to accomplish what is known as the 'Second Green Revolution'.

As a result of the low level of support given to S&T sectors and education, South Asian countries are experiencing a serious crisis in science education and teaching. General sciences, except medicine and engineering, are no longer perceived as attractive career prospects by secondary school students. Eminent scientists who were once role models are being replaced with new ones from areas such as business or information technology. While there is an urgent need for innovation in science teaching to make it more attractive to young students, good science and mathematics teachers are becoming scarce, with many potential teachers being lost to more lucrative occupations. Science now has to compete with other rapidly growing occupations and sectors catalysed by liberalization and globalization, such as economics, business, information technology, fashion design, tourism and leisure. A major effort by both the state and NGOs is needed to rescue science before it loses its shine.

Despite improving trends over the last decade, the major challenge for the gender situation in S&T for the region as a whole remains female education and literacy programmes. Whereas male literacy for the region is

62%, female literacy is a low 36%. The region entered the new millennium with more than 250 million illiterate women, according to Human Development reports in 2003. The focus on female education demands unprecedented policy attention in the coming decades as the new technologies – such as ICTs, biotechnologies and agricultural S&T networks involving research, education and extension – are all knowledge-intensive domains. Apart from the afore-mentioned common challenges and responses, which nevertheless vary across the region, several countries are also embedded in a contextual matrix concerning the role of S&T for development.

In India, S&T policies have by and large concentrated on the input side of the R&D spectrum, while the structures of linkage and diffusion end of the R&D domain remain quite weak and are left to the natural play of different actors in the national innovation system. One major positive consequence of such policies has been to evolve an S&T human resources base. However, from the perspective of national innovation systems (NIS), India needs to graduate urgently from the existing S&T policy regimes to a regime of national innovation policies as is done in Japan and South Korea. Such a perspective entails not only strengthening the main actors of NIS (the academic sector, the S&T and R&D systems, industry sectors and government agencies responsible for good governance) but forging linkages between these actors and the socio-economic system as a whole.

Given the size and economy of China as a competing neighbour, there is a need to increase the existing R&D budget level of 1.08% of GDP to the government-committed level of 2% in the coming three years and to commit 6% of GDP to education. To this end there is a need to increase private industrial R&D. The existing tax R&D incentive schemes lack penal underpinning and this needs to be addressed adequately by the Department of Science and Technology.

The university sector is the most neglected sector, claiming a bare 8–10% of national R&D spend, and the new innovation policies need to balance appropriately the distribution of resources between different actors in the NIS. The future human resources base, the innovation success of new technologies (nanotechnology, biotechnology, bioinformatics and material sciences) and the economic potential of knowledge-based industries including telecommunications are entirely dependent on the strength of higher education and research in the university sector. Moreover, the academic science sector in India needs a very big boost to arrest the current stagnating and declining trends of SCI-based S&T publications at the world level. Defence and strategic-related R&D systems in India have been quite dynamic and attained very high technological capabilities. The future challenge however lies in converting the defence and strategic technological capability (as in the case of space) into useful market-based innovation in the civilian sectors.

Iran, despite considerable oil revenues and a relatively developed educational infrastructure, has failed to make S&T a major factor in the economy. Excessive economic restrictions and a seemingly inward-looking policy over the years have been very telling on the S&T system. A country with a long historical scientific tradition, Iran has experienced a serious setback in the growth of national scientific communities over the last two decades. The lack of autonomy for science as a social system has been one of the serious challenges confronting the scientific community. However, a favourable attitude to science, rationality and development among the general public is catalysing a new social movement in science and development, which is in an embryonic phase.

The major weakness of the Iranian S&T system lies in the area of technological development. Here again, the prevailing situation which prevented foreign investment and technology, alongside an over-concentration of industry in the state sector, has led to serious problems for technological dynamism. The weak R&D system of both public and private enterprise, coupled with poor linkages with the university sector, have failed to catalyse the absorption and assimilation of foreign and high technology. In recognition of the prevailing problems and to keep up with the wave of globalization and liberalization taking place in other countries, restructuring of the R&D system is under way. The well-developed university educational sector and relatively high proportion of educated citizens give Iran an advantage in the race to catch up with the knowledge and information technology industries.

In Nepal, Sri Lanka and Bangladesh, the major stumbling block for the dynamic development of endogenous scientific and technological capabilities is the low level of state support for R&D (0.26% for Nepal, 0.19% for Sri Lanka and only 0.01% of GDP in 2000–04 for Bangladesh). The lack of highly trained professionals in R&D organizations, the underdevelopment of higher education and the science base in the universities, dependence on foreign training in specialized areas of S&T and lack of adequate merit-based professional incentives are problems common to the research systems of these countries. While Bangladesh is yet to come to the level of R&D funding of other countries in the region, the situation is rapidly improving in the case of Pakistan and Nepal which have almost doubled their government support to R&D in the last five years.

A common feature relevant to Pakistan, Bangladesh and Sri Lanka is the existence of more than three-decades-old national R&D organizations such as ITI and NERDC in Sri Lanka, PCSIR in Pakistan and BCSIR in Bangladesh. These can play an important role in the development of national- and firm-level technological capabilities. For instance, the success achieved by the textile and garments sectors in Bangladesh and Sri Lanka recently can be further consolidated and extended to other manufacturing sectors by connecting their needs and demands to R&D institutions. A low level of R&D effort with short-term goals coupled with thin funding spread over a large number of projects seems to be the main problem indicated at BCSIR and ITI. A lack of R&D downstream and design and engineering facilities to upscale technology developed in national laboratories and transfer it to industry, coupled with a lack of state-supported venture capital mechanisms, has led to gross underutilization of the technological capacity of these R&D institutions. The laboratories of the ITI and BCSIR are located in close proximity to the leading universities of Colombo and Dhaka respectively, but there is little mobility and interaction between scientists and academic personnel.

There is a need to develop such linkages between universities and research agencies on the one hand and with industry on the other. Given the low level of R&D funding, in many of these countries including India, there is a need to optimize research efforts in new R&D fields through mobility of professionals, sharing of sophisticated and costly scientific equipment, joint projects and even through the creation of joint laboratories shared by universities and national laboratories as in the case of France. More than 80% of CNRS laboratories have moved during the last decade to operate jointly with French universities.

Strengthening the science base in the universities with an expansion in PhD and R&D programmes, coupled with peer review and standards of excellence, have become pre-requisites in creating a reasonable national innovation base. This takes considerable time. In a way these tasks have become an essential factor in the process of attaining national technological capabilities, particularly in agriculture, bio-resource and health, because these are the fields closely related to basic sciences and academic research capabilities. Another important reason to support universities is for the human resource base. In all these countries including Iran, the realization that the academic sector could emerge as a major source of S&T innovations in the current decade has as yet been very slow to attract the attention of S&T policy planners in South Asia.

Pakistan has provisions for venture capital and for established institutions, such as the Scientific and Technological Development Corporation, to transfer technology developed in the national laboratories to industry. With a considerable number of universities and R&D institutions, including those under PCSIR, there is however a problem of linkages between different sectors. SMEs in engineering products, textiles and chemicals are the fastest-growing sectors of the economy and require R&D support to become competitive through technological means rather than cheap labour. This holds good for other countries in the region.

A considerable achievement in Bangladesh has been the role of the NGOs, catalysed by the collaboration of state agencies, in developing micro-credit institutions, rural health and artisanal innovations and education. Grameen Bank, Gonoshasthaya Kendra (GK), Bangladesh Rural Advancement Committee, Dhaka Ahsania Mission, Proshika and the Underprivileged Children's Educational Programme are among the most notable (see box below). As far as S&T policy is concerned, the role of Gonoshasthaya Kendra – the People's Health Centre, Dhaka (which produces the most essential drugs in its antibiotic factory) – in the formulation of the country's drug policy is most notable.

Micro-credit projects in Bangladesh

Micro-credit finance institutions sponsored by the government and NGOs which have the specific aim of developing the poor sections of society in Bangladesh are beginning to yield significant results in education and information diffusion.

Grameen Bank was set up by Muhammad Yunus in 1983 to make tiny collateral-free loans to the poor to help them set up micro-businesses. As of August 2004, it had disbursed US$ 4.6 billion in loans to 3.8 million borrowers. The Bank provides services in 53 000 villages in Bangladesh (over 70% of the total), lending about US$ 2 million a day in loans of US$ 200 on average. Some 96% of borrowers are women. The bank concentrates on women because they tend to plan for the longer term and be good at repaying loans (99% of Grameen Bank loans are repaid); women also spend more of the business profits on their family than do men, using the profits to send their children to school.

The Grameen Bank's expansion has brought about a phenomenal growth in the number of schools supported by borrowers. Beginning with a modest investment of less than 1 billion takas* annually in 1986, the Grameen Bank had disbursed over 9 billion takas supporting 16 000 schools just eight years later.

Like the Grameen Bank, the Grameen Phone project promotes women's empowerment and information diffusion in rural areas through a credit scheme. Grameen Phone, a nationwide mobile telephone company, enables poor women in villages to market telephone services to their entire village or to individual clients. Besides empowering women, the project connects villages to markets in cities. Villages also benefit in terms of education, health and other informational needs. To date, Grameen Phone has distributed more than 2 000 mobile phones to 'phone ladies' in as many villages.

The founder of the Grameen Bank is currently working with Hewlett-Packard to bring Internet kiosks to villages. These Grameen Digital Centres will be designed so that even illiterate villagers can operate them using touch screens and voice commands.

Another multifaceted project is the Bangladesh Rural Advancement Committee (BRAC). This institution combines training with credit by imparting skills to promote micro-enterprises in such activities as vegetable growing, silk production, livestock, fisheries and forestry. More than 280 000 clients have benefited from these activities and learned about their legal rights with regard to family and business.

See also: www.grameen-info.org/bank/

* In June 2005, 100 Bangladeshi takas were equivalent to US$ 1.57.

Bhutan and Myanmar are still building infrastructure in S&T while they are in the process of institutionalizing science. The major challenge for these countries (the group includes Nepal, Sri Lanka and Bangladesh) in the coming decade is to create viable science communities which will play a key role in the development of agriculture (including animal husbandry, milk production, animal health and veterinary services) and in realizing the economic potential of local biological diversity. Agricultural processing, including dairy and milk processing, textiles, ready-made garments and chemicals are important areas in the manufacturing value added in these countries. Wood products in Myanmar and Bhutan and tourism in Nepal are other specific sectors. The future growth of the manufacturing sector will increasingly depend on the extent to which these countries develop and deploy professional engineering and technical skills to improve the existing 'flexible specialization'. They are crucial for absorbing the imported technology and developing local technical capabilities.

As a large proportion of the labour force (about 94% in Bhutan and Nepal and 73% in Myanmar) is still dependent on agriculture, strategies to manage the transition from agriculture to industry and services calls for a major educational effort in vocational and technical skills. In small countries, retaining the trained scientists and engineers is becoming much more important than training itself. Studies indicate that providing incentives and creating a professional climate are likely to arrest the process of brain drain. S&T policies directed to arrest brain drain and foster brain gain are likely to assume unprecedented importance in the near future because of the shortage of skills in the industrially developed countries in Europe, North America and Australia.

The Maldives, with a population of 0.25 million, is one of the smallest countries in the world. The country has the highest adult literacy and primary enrolment rates in the region (97% and 100% respectively) but still lacks a tertiary institution. The major challenge for the country is to establish such an institution, which will network with neighbouring countries to draw on knowledge and information.

In Mongolia, the S&T structure is still undergoing a transformation to keep up with the new policies towards a market economy and liberalization. With the limitation of a small economy and population, the major challenge in technological innovation is to attain international competitiveness. With a relatively high proportion of scientists and engineers per million of the population, the country has the potential for integrating and commercializing new and high technology. But this will depend on the extent to which new S&T policies introduced in 1997 will be able to forge fruitful partnerships in university/industry relations.

South Asian countries are predominantly agrarian and are likely to experience rapid transformation in the coming decade. From an overall perspective, a cursory look into the pattern of technology trade since the 1970s reveals an important lesson for these countries. Between 1976 and 1996, the shares of resource-based primary products and low-technology goods in total international trade came down from 45% and 21% to 24% and 18% respectively; and the shares of high- and medium-technology goods went up from 11% and 22% to 22% and 32% respectively (World Bank, 1999, p. 28). This trend continued for 2000–04 as indicated by the increasing share of the service sector. In other words, natural resource endowments and low-skilled cheap labour are unlikely to give a comparative advantage to our economies in the future. It is value addition through new skills, technological change and knowledge, coupled with appropriate institutional and organizational innovations, that will play a key role in the comparative advantage of South Asian countries.

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