HED/POL/2007/PI/49

UNESCO FORUM
on Higher Education, Research and Knowledge

Study on National Research Systems
A Meta-Review

REGIONAL REPORT ON ASIAN COUNTRIES

Compiled by J. Mouton

2007

UNESCO

United Nations
Educational, Scientific and
Cultural Organization

Published with the support
of the UNESCO Forum for
Higher Education, Research and Knowledge

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UNEDITED VERSION

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DECEMBER 2007

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SECTION 1: INTRODUCTION

Our review of Asian countries produced country reports for 10 countries: Bangladesh, Indonesia, Malaysia, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Thailand and Vietnam. [1]

Although these countries were selected because they met the criteria (developing countries and not well-researched) for inclusion in this review, there are still significant differences in their science and technology systems. These differences are due to many factors: socio-political histories, geography, political and economic (in)stability, different legacies of colonial science influence and subsequent science institutionalization development and so on.

One example of the differences between the seventeen countries is illustrated by differences in scientific output as measured by articles published in the ISI-indexes. In terms of this measure, one would distinguish between three clusters of countries: those countries (Singapore) that produced more than 2000 publications between 2001 and 2004 (Tijssen, 2006); another cluster of countries (Malaysia and Pakistan) who produced at least 500 publications and then the remaining countries who produced less than 500 or – stated differently- less than 100 articles on average per year.

However, publications in ISI-journals are not necessarily the best indicator of science in a country, especially in developing countries, where there are many "informal" scientific institutions who produce science in various non-standard dissemination media. Also, it is well documented that journals in "marginal countries", are not well-represented in ISI-indexes.

SECTION 2: SUMMARY INDICATORS AND DESCRIPTORS

[1] This regional report is based on the individual country reviews contained in the Asia compilation as well as some additional references. The authorship(s) of the individual countries in the Asia compilation are clearly identified and acknowledged in the compiled report. In summary, therefore, I only list here the individual authors of the country reviews: VV Krishna, Usha Krishna, S.T.K. Naim and Seetha Wickremasinghe.

Table 1: General demographic and S&T indicators

Country	Total Pop millions 2003 (WDI 2005)	HDI rank (UNHDR 2006)	PPP gross national income/ Per capita $/ 2003(WdI 2005)	PPP gross national income/ Per capita / Rank 2003(WDI 2005)	GERD/% GDP	Head-count of researchers	Nr of researchers per million of pop	ISI- papers (2002 – 2004)	SCI pubs per 100 000 of pop
Bangladesh	138.1	137	1870	163	0.03%	15364	46	1324	0.35
Indonesia	214.7	108	3210	142	0.05%	92817	438	1339	0.22
Malaysia	24.8	61	8970	81	0.69%	24937	180	3359	4.82
Nepal	24.7	138	1420	179		13500	118		0.56
Pakistan	148.4	134	2040	159	0.24%	12820	86	2357	0.57
Philippines	81.5	84	4640	128	0.11%	8692		1274	0.57
Singapore	4.3	25	24180	30	2.15%	28825	4745	14193	118.44
Sri Lanka	19.2	93	3740	136	0.19%	16851	393	666	1.45
Thailand	62	74	7450	87	0.26%	76814	286	5686	3.18
Vietnam	81.3	109	2490	151				1255	0.61

Table 2: Higher Education Indicators

	Total HE enrolment 2004[2]			Teaching staff (2004)[3]		Total number of graduates (2004)[4]		Total public expenditure on education (2002-2004) as a % of GDP[5]
	MF	%F[6]	% Private	MF	%F	MF	% F	
Bangladesh	821 364	31.6%	---	46503	17.4%	---	---	2.2
Indonesia	3551092	43.8%	---	271540	39.4%	612975	48%	0.9
Malaysia	731077	55.4%	---	47072*	46.9%*		55%	8.0
Nepal	147123	27.6%	---	---	---	---	---	3.4
Pakistan	520666	42.7%	---	60633*	13.1%*	---	---	2.0
Philippines	2420997	55.2%	---	113803	55.7%	401928	59%	3.2
Singapore	---	---	---	---	---	---	---	---
Sri Lanka	---	---	---	---	---	---	---	---
Thailand	2251453	53.7%	---	---	---	481895	50%	4.2
Vietnam	1328485*	40.9%*	---	46729*	40.5%*	---	---	---

*Provisional figures

[2] http://stats.uis.unesco.org/unesco/TableViewer/tableView.aspx - Table 15 accessed 23 November 2007
[3] http://stats.uis.unesco.org/unesco/TableViewer/tableView.aspx - Table 4; - accessed 23 November 2007
[4] http://stats.uis.unesco.org/unesco/TableViewer/tableView.aspx - Table 16; - accessed 23 November 2007
[5] Source : Human Development Reports: http://hdrstats.undp.org/indicators/99.html

[6] http://stats.uis.unesco.org/unesco/TableViewer/tableView.aspx - Table 14; - accessed 23 November 2007

Table 3: General science "system" descriptors

Country	*S&T Policy Document*	*Ministry of S&T*	*Research Funding Agency*	*Nr of public universities*
Bangladesh	Yes (1986)	Ministry of Science and Information and Communication Technology (MOSICT) (1983)		21
Indonesia	Yes	Ministry of Research and Technology (1970)	National Research Centre for Science and Technology (called PUSPIPTEK)	82
Malaysia	Yes (1986) Revised (2003)	Ministry of Science, Technology & Innovation (MOSTI)	National Council for Scientific Research & Development (NCSRD)	17

Nepal	Yes (1980 – 1985)	Ministry of Environment, Science & Technology (1996)	National Council for Scientific Research (NCST) OR Royal Nepal Academy of Science & Technology (RONAST)	
Pakistan	Yes (1976 – Draft)	Ministry of Science & Technology (1962)	Pakistan Science Foundation	37
Philippines	Plan?	Department of Science & Technology	National Academy of Science and Technology (NAST AND/OR (2) National Research Council of the Philippines (NRCP).	
Singapore	Plan?	Ministry of Trade & Industry	Public sector: Agency for Science, Technology & Research (ASTAR) Private sector: Singapore's Economic Development Board	9
Sri Lanka	Yes (1969)	Ministry of Science & Technology		13
Thailand	Plan?	Ministry of Science & Technology & Environment	National Research Council/National Science & Technology Agency	20
Vietnam		Ministry of Science & Technology		202

SECTION 3: SUMMARY FINDINGS FROM THE COUNTRY REPORTS[7]

Introduction

In order to understand the research systems in the ten Asian countries reviewed, it is important also to understand how human capital development and technology development are related in these countries. In a very interesting and useful analysis of the relationship between "Technology and human capital in maturing Asian countries", Sanjaya Lall (1998)[8] proposed the following threefold classification of countries in the region in terms of industrial maturity:

1. The *Four Tiger Economies*: Singapore and Korea. These were in the late twentieth century the industrial leaders within the region and constituted some of the most competitive countries in the world.
2. *Three New Tigers*: Indonesia, Malaysia and Thailand: These countries followed an export-oriented industrialization path but have recorded sustained expansion and deepening of their industrial sectors.
3. *Three* Large Inward-oriented Economies: China, India and Pakistan. According to Lall these countries at the time comprised large industrial sectors with some relatively advanced capabilities, but were only starting to emerge as significant exporter economies.

Even though Lall's analysis is clearly dated in that more recent events – especially with regard to the performance of China and India – has made this classification somewhat inaccurate, it remains useful as a general frame of reference. It is particularly pertinent, as we will argue in the first section below, as it again reminds us of the close link between economic and industrialization policies on the one hand and S&T policies and developments on the other.

But his analysis is also useful for another reason. Lall also analyzed the human capital strategies followed by these countries. Looking at tertiary enrolment data in some detail (especially with regard to enrolment in technical subjects), Lall concludes his analysis with the following:

[7] The summary and synthesis presented in this report is based nearly exclusively on the ten country reviews included in the Asian compilation. I have only attempted to synthesize, summarize and draw high-level patterns from the very detailed individual country reviews. I have often used passages from these reports verbatim without necessarily referencing each one as is often the case with synthesis reports. Of course, I take full responsibility for those interpretations and conclusions that I have drawn and which often go beyond the material contained in the individual country reviews.

[8] S. Lall (1998) Technology and human capital in maturing Asian countries. *Science, Technology and Society* 3(1): 11 – 48.

> *It is clear that the Tigers and Singapore have advanced the furthest in creating a broad educational base that is required by human capital development. The Korean effort overall is impressive, but it is particularly remarkable in terms of the output of university trained technical personnel: it is this which provides the 'brain-power' for the immense industrial machinery. … The new Tigers have, in comparison, shown relatively weak performances in education and training… Enlarging, broadening and improving the educational base thus have to be a top policy priority for these countries… The large inward-oriented countries have the weakest human capital base for sustained industrial upgrading*. (Lall, 1998: 31 – 32)

The relationship between S&T, industrialization and human resources for S&T is equally important in understanding how different research systems have developed and "performed" over the years. We return to this theme in Section 3.4 below.

3.1 Recent trends in governance and policy development in S&T

The review of science policy development paths in the individual ten countries included in this regional report suggests at least three "clusters" of countries with different trajectories.

- A first cluster of three countries – Singapore, Malaysia and Thailand – where science and technology policies developed more as the result of industrialization policies and plans (this is especially true of Singapore and Malaysia).
- A second cluster of countries where science and technology goals and priorities were subsumed in more general macro-economic plans that were centrally driven (Indonesia, Philippines and in the socialist Republic of Vietnam)
- A third cluster of the poorer countries in our review – Bangladesh, Nepal, Pakistan and Sri Lanka – who were early developers of formal science and technology policy documents (very soon after independence) but where investment in R&D is also of the lowest.

It is important to emphasize that this threefold classification generates rather "loose" clusters only with regard to science policy development. The research systems of the countries in the same cluster differ from each other in significant ways which are discussed below.

Trajectory 1: Science policy development dominated by industrialization policy

Singapore: Singapore became independent from Malaysia on the 9th of August 1965. In the 1960s import substituting industrialization was replaced with rapid industrialization through attracting foreign investment for export oriented and labour intensive manufacturing. The export-led industrialization strategy was supplemented by moves to develop Singapore into a regional and international financial centre. Foreign exchange controls were removed and various financial incentives introduced. S&T was first identified as a priority in 1968 when the Ministry of Science and Technology was established to promote the role of science and technology in the education system and the economy. In 1967, the Singapore Science Council was established as an advisory body on work force training and R & D in industry. Early in 1991, the Government set up the National Science and Technology Board. This Board produced in August 1991 the National Technology Plan 1991 outlining a comprehensive and coordinated national strategy for R & D for the next 5 years. The plan emphasized the role of R & D in providing industrial competitiveness.

The success story of Singapore is by now well documented. One indicator of its success in becoming an industrially competitive economy is R&D intensity (as measured by Government Expenditure on R&D [GERD] as proportion of Gross Domestic Product [GDP). In 2004, expenditure on R&D was $4,062 million, which constituted 2.25% of gross domestic product (GDP) and one of the highest in the world. The contribution of private sector to R&D is noteworthy as they contributed 64% ($2,590 million) of total expenditure on R&D and amounted to 1.43% of GDP, in 2004. The government sector was 11%; higher education sector 10% and the public research institutes 15% of total expenditure on R&D. Private sector expenditure on R&D increased 24% from $2,081 million in 2003 to $2,590 million in 2004. As a percentage of gross domestic product (GDP), private sector expenditure on R&D increased from 0.46% in 1990 to 1.43% in 2004 trebling in 14 years.

Malaysia: Malaysia transformed from a country dependent on the production and export of primary commodities to an emerging multi-sector economy over the period from 1971 through the late 1990s. During the last decade, the country emerged as a leading exporter of high technology products. Its recent growth is almost exclusively driven by exports - particularly of electronics, followed by palm oil and palm oil based products and other manufactured goods and articles. The services sector contributes 57% of the gross domestic product (GDP), manufacturing constitutes 30% of GDP, while a lesser amount is contributed by the traditional sectors of agriculture and forestry (8.4% of GDP) and, mining and quarrying (7.2% of GDP).

Malaysia's S&T development has thus far been based on its S&T Policy which was adopted in 1986. The tenets of this policy were implemented through the National Plan of Action for Industrial Technology Development (1990). The S&T policy went through a review process in the year 2000, and this resulted in the formulation of the Second National Science and Technology Policy (STP II), which was launched in the year 2003. The Institute for Management Development (IMD) in its 2004 World Competitiveness Yearbook ranked Malaysia as the fifth most competitive country in the world (for countries with a population of greater than 20 million). It is perhaps then not surprising that investment in R&D has been fore grounded and increasingly so: from 0.37% in 1992 to 0.69% in 2002. It is also noteworthy that 65% of R&D in 2004 was funded by the private sector.

Thailand: Although not in the same league as Singapore or Malaysia, the more recent economic policies of Thailand have included an emphasis on S&T. S&T initially did not receive much attention in the national development plans until about the Fourth Plan. It was only in Fifth Plan (1982-86) that the government had a chapter on S&T for development. What is further of interest is its adoption of the concept of national innovation systems and industrial clusters in the most recent ten-year Science and Technology Action Plan (2004-2013). The main objectives of the plan are to enhance Thailand's capabilities in response to rapid changes in the age of globalization and to strengthen the country's long-term competitiveness.

Gross expenditure on R&D (GERD) as proportion of GDP increased from 0.21% in 1987 to about 0.26% in 2002 which is quite low compared to neighbouring dynamic economies of Asia, namely, South Korea, Singapore and even Malaysia.

Trajectory 2: Science and technology subsumed in (central) macro-economic planning

Central economic planning is most closely and obviously linked to socialist regimes. This is certainly the case in Vietnam in our review. However, although not explicitly socialist, the governments of Indonesia and the Philippines also followed over the recent past very rigorous central economic planning as expressed in 5-yearly plans. Within these frameworks, S&T were always seen as secondary (and even derivative?) to economic priorities rather – as more recent studies would suggest – as the driver of economic growth and wealth creation.

Indonesia - In the 'Constitution 1945 of Republic of Indonesia' chapter 31 assigned an important role for S&T in the development of the country. From 1950, Indonesia started its programme of expanding education at all levels and science and technology. In 1956, the government formed the Indonesian Council of Sciences to coordinate developments in S&T and to advise the government on science and technology policy. What is noteworthy about the "development" of science and technology in Indonesia is that it formed part, until recently of the Government's macro economic development plans. The first such five-year plan (PELITA I) commenced in 1969 and concluded in 1974. Science and technology activities during PELITA III (1979-80 to 1983-84) were grouped into pure and applied sciences, supporting each other and directed towards the requirements of short and long-term developments. The fifth Five Year Development Plan (PELITA V) laid down the task for the National Research Council to prepare the formulation of the principal National Programme in the fields of research and technology through planning and national development strategy.

Philippines: Agenda setting for S&T in the Philippines is embodied in successive S&T development plans through the years. There was the S&T Master Plan 1990-2000 (STMP) developed during the regime of President Aquino; the Science and Technology Agenda for National Development (STAND) 1993-1998 developed in 1993; the DOST Medium-Term Plan (MTP) 1999-2004, which was actually only a departmental plan; and the recent National Science and Technology Plan 2002-2020 (NSTP).

What is disappointing about S&T in the Philippines is that despite the inclusion of S&T in the five-yearly development plans, expenditure on R&D has been declining systematically from 1992 (0.2%) to 2002 (0.1%). This has been accompanied by a similar decline in the number of research workers in the system: from 15 600 in 1992 to 8 700 in 2002. The biggest decline occurred in the government sector. In addition nearly 60% of government expenditure (2002) was devoted to agricultural and industrial production and technology while about 14% was spent on environment and human health. It is clear that agriculture constitutes a considerable proportion of the R&D budget. In Philippines, the agriculture sector has a well-developed R&D system relative to the other sectors because the government recognizes the public nature of agricultural R&D.

Vietnam: As early as in the late 1950s, a national agency for S&T was established to coordinate and promote S&T. During the 1960s and 1970s, even at the height of the American War, a large number of scientists and engineers were educated in socialist countries and numerous R&D institutes and universities were created by the government.

After the liberation in 1975, the country embarked on building S&T institutions and organized science and technology drawing inspiration from the Soviet Union. S&T was seen as a vital part of a largely self-contained, self-sufficient economic development model. The number of government R&D institutes and centres mushroomed in the period up to the late 1980s. Since the adoption of the *doi moi* (renovation) policy in 1986, far-reaching changes have been taking place. The state budget is no longer the only source of funds for R&D, and more and more funds are coming from industry and other sources.

More recent trends in Vietnam have been towards greater liberalization of higher education and science. The government no longer administers and controls all the R&D organizations and universities, and many collective and private R&D organizations are now in operation.

Trajectory 3: Early developers (adopters?) of science policy but low investment in R&D

The four countries included in this cluster all initiated the development of their first S&T policy documents as well as putting in place the first formal governance structures for S&T soon after achieving independence. But these countries also share one other common feature: at the time of independence none of these countries necessarily had a rich legacy or well-established S&T infrastructure in place – despite some efforts in this regard under former colonial rule. It is perhaps fair to say that whereas colonial science in other parts of the world (e.g. Australia or India) led to the establishment of notable scientific institutions, this was not the case in these countries.

Bangladesh The area that is now Bangladesh was part of the old Bengal Province of India under British rule and most of the S&T infrastructure and R&D institutions were located in and around Calcutta, the capital of the province. As our country review shows, the only research station inherited in 1947, when British rule ended and the country was partitioned, was an agriculture research institute specializing in rice research. After independence in 1971, Bangladesh found itself in a difficult economic situation with a weak R&D infrastructure. The country was forced to build new R&D institutions and technical universities. The National Council for Science and Technology (NCST), created in 1983, is the main apex body for science and technology at the highest level for policy-making on S&T in the country. It worked for three years to draft a S&T policy, which was formally approved by the government in 1986.

Sri Lanka: According to the country review, the period following independence, saw a form of 'colonial legacy' which continued in Sri Lanka and which paid little attention to the development of an indigenous science and technology base. One of these colonial institutions, the Ceylon Association for the Advancement of Science (CAAS), the predecessor of the Sri Lanka Association for the Advancement of Science (SLAAS), voiced its opinions about the professionalisation of science and developing local scientific institutions as early as 1944. After independence in 1948 a notable science policy initiative from CAAS in 1950s was its submission of a memorandum to the government for the establishment of National Research Council to foster scientific and industrial research. It was mainly because of the CAAS efforts that the government set up the Ceylon Institute of Scientific and Industrial Research (CISIR) in the 1950s. Exploring the historical growth of S&T policies reveals that even though the country established a number of R&D institutions after independence in 1948, there was no formal S&T policy or document from the government until about late 1960s.

Nepal: The beginning of national S&T policies in Nepal can be traced to the early 1960s. The country report indicates how the government sought the assistance of UNESCO to advise on the formation of a body for the formulation of a Science Policy. In 1966, a detailed survey of scientific infrastructure was prepared under the commission of UNESCO – perhaps one of the earliest efforts of this nature? The Second General Assembly of the National Commission for UNESCO held in 1966 for the first time recommended long-term science planning on a national scale. During the assembly, the Science and Technology Sub- Committee also proposed the establishment of National Council for Scientific Research for the co-ordination and implementation of scientific research activities (NNC/UNESCO 1966). The recommendations also emphasized that the scientific capabilities of the university sector be strengthened. A series of meetings between government institutions concerned with science and UNESCO led to the institutionalization of science policy mechanisms and the establishment of the National Council for Science and Technology (NCST). The main objective of the NCST was to formulate a national Science and Technology policy. The council contributed to the formulation of the first Science and Technology policy that was mentioned for the first time in the Sixth Five Year Development Plan (1980-1985).

Pakistan: Pakistan's independence and partition from India did not result in a positive outlook for science and higher education. Pakistan inherited only four of forty laboratories established in pre-partition India. Out of 20 universities, only one fell into the territory of Pakistan. Soon after the inception of Pakistan, the government recognized the importance of science and technology and established a number of R&D organizations. Simultaneously a number of colleges and universities were established to increase the number of R&D personnel. The potential of agriculture was also realized and great emphasis was laid on the development of agriculture related R&D organizations. The Ministry of Agriculture established the Central Cotton Committee in 1948 followed by the Food and Agriculture Council in 1949. The Council of Scientific and Industrial Research was established in 1949 as an attached department of the Ministry of Industries. This Council was made autonomous and renamed the Pakistan Council for Scientific and Industrial Research (PCSIR) in 1953. It has since established 16 laboratories in major cities of Pakistan. The Pakistan Medical Research Council was also established in 1953 and the Atomic Energy Research Council in 1956. While the initial phase of institutionalization of science and technology continued in the late 1940s and 1950s, the formal formulation of policies for science and technology would only commence in the 1960s

3.2 Contemporary institutional landscape

As we pointed out in our Regional Report on sub-Saharan Africa, different science systems have very different institutional arrangements and forms. Modern science systems have evolved very differently in different parts of the globe and have produced very different types of research institutions. However, it is also fair to say that most modern science systems have a number of typical features:

- There is a core of relatively stable and well-resourced scientific institutes
- There is consistent government and industry investment in R&D at these institutes

- Scientific institutions flourish under conditions of economic and political stability and within a science governance system that allows for their autonomous and relatively independent operation

In addition, given the pervasive colonialism that characterized the majority of countries in our review (with the exception of Thailand, the other nine countries were at different periods in their history under Spanish, Portuguese, Dutch, American, Japanese and British rule!) it would be surprising if some form of colonial influence is not visible in the institutions of science in these countries.

Political instability, especially in the form of prolonged wars (as in Vietnam) or for shorter periods in Indonesia and Sri Lanka, generally is detrimental to the flourishing of science and research in a country. But political stability is, of course, not synonymous with democratic governments. In many of the countries under review, political stability was established under dictator and/or one-party political systems.

We indicate how some of these themes are manifested in the individual countries reviewed.

Bangladesh: Lasting colonial legacy: The influence of British rule in India, Pakistan and Bangladesh is clearly illustrated in the adoption of the British CSIR model in Bangladesh. The major activities that could lead to viable outputs for industrial technology development are concentrated in the Bangladesh Council of Scientific and Industrial Research (BCSIR). The BCSIR is the only government-sponsored industrial research organisation with the mandate to play a crucial role in the country's industrial development. The BCSIR has a total staff of around of about 1200, out of which one-third are scientists and technologists in the year 2003.

Indonesia: Dependency and late institution building

The first organized scientific activities in Indonesia started in 1778 under Dutch rule with the founding of the “Batavia Society of Arts and Sciences”, a private organization for the promotion of research for the benefit of trade and agricultural development. Our country review points out that although the work of its members initially covered all fields of science, their interest gradually shifted more and more to the social sciences. Even to the present period, the “Proceedings” of the Batavia Society of Arts and Sciences remain an important source of knowledge concerning the social and cultural life of the people in several parts of the Indonesian

Archipelago. The establishment of the famous Botanical Garden in Borgor in 1817 was the starting point of systematic botanical research. Gradually more and more research activities were carried out in other fields such as zoology, geology and marine sciences. But during Dutch rule, most scientific research was undertaken by Dutch scientists with little indigenous scientific capacity being built. It was only after independence in 1945 that this trend was reversed.

The legacy of long-standing Dutch support for science and technology in Indonesia – that goes back to the late eighteenth century – thus did not translate in the development of local institutional capacity in S&T in Indonesia. It is only after independence in 1949 that one witnesses large scale growth in the number of higher education institutions as well as in the number of government-funded R&D performing institutes – especially in the field of agriculture.

Although Indonesia has a number of “flagship” institutions in strategic areas such as Atomic Energy and Aerospace research, the establishment of such institutes is not indicative of high R&D intensity. In fact, compared to countries such as Singapore, investment in R&D remains very low staying around 0.2%. This probably also explain the role and influence of a rather large number of international research agencies in Indonesia – especially again in the field of agriculture.

As our country review documents, international agricultural research centres play an important role in Indonesia’s agricultural research system. There are a number of international research agencies conducting research in Indonesia. These are the Centre for International Forestry Research (CIFOR) and the SE Asia regional offices of the International Centre for Research on Agro-Forestry (ICRAF) and the International Potato Centre (CIP). The UN ESCAP CGPRT Centre, which conducts socioeconomic research on secondary food crops, and the ASEAN-funded South East Asia Regional Centre for Tropical Biology (BIOTROP) are also located in Indonesia. IAARD has cooperative research arrangements with several other international agricultural research centres as well (including AVRDC, CIMMYT, ILRI, and IRRI) and agricultural research institutes in Japan, Europe, North America, and Australia. IAARD established a semi-autonomous foundation in 1999, the Intellectual Property and Technology Transfer Management Office (IPTTMO), to help commercialize IAARD innovations. This office has responsibility for patenting and licensing IAARD innovations to private firms.

Building on the colonial legacy: The case of Nepal

Various scientific institutions were established in Nepal under British rule: the Agriculture Office, in 1924; the Civil Medical School for "Compounders" and Dressers in 1934; Technical Training School for Sub-Overseers in 1942); and the Forest Training Centre for Rangers in 1942. The first College imparting science was begun in 1919. On gaining its independence in 1950, Nepal embarked on the path of modernization. Following the development plan of 1956, the Nepal Government also took the initiative to develop infrastructure for S&T activities.

The departments of Irrigation, Hydrology and Meteorology, Mines and Geology, Survey and Medicinal Plants were among the first government S&T institutions to be established in Nepal. Many of these institutions were established within the Ministry of Forestry. The Ministry has promoted the establishment of some other pioneering organizations such as the Royal Drugs Research Laboratories, Royal Drugs Limited, the National Herbarium and Plant Tissue Culture Laboratory, the Forest Research and Survey Centre, the Central Food Research Laboratory, the Herbs Processing and Production Limited and the Department of Drug Administration. The continuing British influence is evident in the names of some of these laboratories.

Political instability and the challenge of building scientific institutions: Sri Lanka

Over the last decade, the weakening economic situation, compounded with ongoing civil conflict, has had a telling impact on Sri Lanka's S&T. This is best illustrated by the stagnation in R&D expenditure over the last few years. In real terms the GERD to GDP ratio witnessed a sharp decline from 0.30 in 1966 to 0.19 in 2000. The impact of these low levels of R&D investment has also had a debilitating effect on human capital in S&T. The available records from various sources show that the number of scientists in the R&D institutions had increased almost nine fold from 204 in 1984 to 1972 in 1996 but has decreased to 685 in 2000. As the R&D Survey (2000) of the NSF indicates, R&D institutes accounted for only 13% of the total scientific human resources while the rest is accounted by the universities. Further, as our country review shows, there has been either relative stagnation or only marginal increase in the endowment of scientific human resources in most of the R&D institutes between 1998 and 2004. For instance in ITI, the country's main industrial research laboratory, the institute employed a total of 329 personnel out of which only 21% (69) were scientists and engineers in 1998 which decreased to 67 in 2004 (see ITI 1998). Another major R&D institute of Sri Lanka - the National Engineering Research and Development Centre (NERDC) -also suffered with low level of human resources during the last decade even though there has been a marginal increase between 1998 and 2004 from 39 to 47.

No colonial legacy: Thailand

In Asia, unlike other countries, Thailand was not under colonial rule. With origins in Chinese culture, Thailand adopted Brahmanic system of justice and Therevada Buddhism as its state religion. The history of modern science in Thailand can be traced to the ascendance to throne of King Mongkut of Chakri dynasty in 1851; and his successor King Chulalongkorn. The latter was the first King to travel to European countries and the first to send royal family members and others to study and draw western educational experiences from Europe. He founded the first Thai university, Chulalongkorn University in 1916. However, the first modern science related institutions were established in the late 19^{th} Century beginning with Paetyakorn Medical School in 1889; Law School in 1897; Royal Pages School for administrators in 1902 on the lines of the French Grandes Ecoles . The European influence continued into the 20^{th} Century, mainly from 1940s when the country embarked on building modern higher educational and S&T institutions.

The influence of the Soviet academy of science model: Vietnam

One of the key features of former socialist regimes in central and Eastern Europe and the former Soviet Union, was the prominence accorded to the prestigious and well-resourced Academies of Science. This is certainly still the case in Vietnam. Among all scientific and engineering organizations, the Vietnam Academy of Science and Technology is the largest one. The institute has 18 research institutes and 9 regional branches in various fields of science and engineering. Their affiliates are located in all parts of Vietnam with concentrations in Hanoi and Ho Chi Minh City. The institute set up 16 enterprises; 21 scientific centres (under 35 Degree); 16 higher education institutions; 7 administrative bodies and 11 journals/magazines. By the end of 2003, this institute had a staff of about 3000 people. Another state scientific research institution is the Vietnam Social Science Institute. By the end of 2003, the centre had 26 research and supporting institutes; 4 administrative bodies; 15 higher education institutions and 30 journals/magazines and employed 1380 people. Traditionally, the above two institutes have privilege to receive funding from central government to carry out the so-called "State S&T missions".

In addition to the more general discussion of scientific institutions in some of the countries in our review, we also devote some attention to the role of universities in these countries in Section 3.3 below.

3.3 The role of the universities in public R&D

Very limited to negligible contribution

Bangladesh is an example of a science system where little research is being done at the universities. Research there is funded through the University Grants Commission but given low levels of government support for R&D these funds are quite limited and have not increased over recent years. It seems that public R&D in Bangladesh is confined mostly to government organizations (BCSIR and ARC) with little support for university-based research.

Nepal: Besides some departments at the science faculty of Tribhuban University, there are 4 institutes which conduct research: Institute of Agriculture and Animal Science, Institute of Engineering, Institute of Forestry and Institute of Medicine. Research Centre for Applied Science and Technology (RECAST). Research activities are also carried in other universities such as Kathmandu University, Purbanchal University and Pokhara University. However, much of the research carried out in the university sector mainly relates to higher education research at the masters level and only occasionally medium term R&D projects are undertaken.

Expanding but limited HE sector

Higher education in Indonesia began at the end of the Nineteenth Century with the establishment of medical education for local doctors in Jakarta. As our country report shows, after independence in 1949 and in particular after promulgation of the Education Act of 1961, the country witnessed significant progress in higher education. In 1950, there were 10 institutions of higher education with 6500 students. By 1970, there were 450 private and state funded institutions of higher learning with enrolments of 237,000 students. This increased further to 900 institutions in 1990 with nearly 1.5 million students.

However the country review does not indicate that this expansion in higher education has translated into a major role for the universities in the national R&D effort with only 5.6% of national expenditure on R&D in the period 2000 – 2002 being undertaken within this sector. It seems as if the sector is seen mainly as the training ground for high-level workforce rather than as sites for knowledge production. This might possibly also explain the very low output of Indonesia – given its size – of scientific papers as measured by the ISI Web of Science.

Pakistan

Pakistan is another example where R&D in the Higher Education sector is very limited. Despite the fact that there are 37 public universities, only the Quaid-e-Azam University of Islamabad, nine centres of excellence and some institutes were involved in postgraduate research. This is not surprising if one keeps in mind that only 30% of staff in these universities have PhD degrees. The Universities Grants Commission was reconstituted as the Higher Education Commission (HEC) with the mission of introducing quality in teaching, research, management and governance of universities. The HEC's major initiatives include the Foreign Faculty Hiring Programme where 300 teachers, both expatriate and foreign are hired to teach at universities on international pay scales. HEC has also launched programmes to increase PhD-level work force from the present 2800 to 8000 over the next 5 years. Each year about 250 PhD students are sent to universities in Germany, France, Austria and China. To encourage quality research, emoluments of scientists and engineers working in the public sector universities and R&D organizations have been substantially increased by linking their research performance to a Research Productivity Allowance (RPA) and Special Science & Technology Allowance. Tenure track system of appointments has been introduced in universities to increase the salaries of faculty and link it to performance. These steps are designed to introduce quality in teaching, promotion of research and to reduce brain drain. This situation poses major problem for Pakistan universities to produce adequate research personnel for science and technology institutions, which is being augmented by various programmes and schemes, mentioned above.

3.4 Current state of human and infrastructural resources

In a comprehensive review of the latest statistics related to human resources in S&T, the NSF in 2007 released a report entitled "Asia's rising science and technology strength"[9]. I have included some tables from this report as they shed light on the challenges that our ten countries face in the area of human resources development.

Education level of the labour force

[9] NSF (2007) *Asia's rising science and technology strength: Comparative indicators for Asia, the European Union and the United States*.

The number of workers who have completed at least a tertiary degree are available for most countries and can serve as an approximate indicator of the growth of a more skilled workforce. The number of people in the world who have completed a tertiary education rose from an estimated 139 million in 1990 to 193 million in 2000 at an average annual growth rate of 3%. (Source: NSF: 2007). Between 1990 and 2000, all major Asian economies experienced significant growth in the tertiary-educated labour force, averaging 5% annually (closer to 6% if Japan is excluded) and a rate similar to that of the EU.

Table 4

Estimated tertiary-educated workers by country: 1990 and 2000[10]

Asian and country region	**1990**	**2000**	**Increase**	**Average annual increase (%)**
Indonesia	235,000	736,000	501,000	12.1
Malaysia	210,000	418,000	208,000	7.1
Philippines	3,556,000	5,698,000	2,142,000	4.8
Singapore	33,000	86,000	53,000	10.1
South Korea	2,035,000	4,442,000	2,407,000	8.1
Thailand	1,705,000	3,185,000	1,480,000	6.4
EU-15	13,486,000	22,415,000	8,929,000	5.2

Source: NSF (2007) *Asia's rising science and technology strength*.

If we focus on the production of graduates in the field of S&E, a useful indicator is the number of Bachelor's degree awarded in these fields. Table 5 below shows that the number of S&E Bachelor's degrees rose significantly in the 1990s in Asia.

[10] The NSF report unfortunately does not include any statistics for Bangladesh, Nepal, Pakistan, Sri Lanka or Vietnam. I have included the statistics for South Korea as it provides a useful reference point to one of the most successful economies of the region not included in our review.

Table 5

Science and engineering bachelor's degrees and engineering baccalaureates by country: 1990 or closest year and 2002 or most recent year

Asian and country region	**1990 or closest year**		**2002 or most recent year**	
	S&E	**Engineering**	**S&E**	**Engineering**
Indonesia	30,700	9,800	97,100	20,600
Malaysia	3,400	900	4,800	900
Philippines	71,100	29,400	NA	NA
Singapore	3,700	1,200	5,600	1,700
South Korea	79,300	28,100	113,100	64,900
Thailand	24,200	6,800	31,200	10,900
EU-15	284,300	92,700	506,100	198,300

Source: NSF (2007) *Asia's rising science and technology strength*.

But the increase in S&E graduates also brings it with the spectre of brain drain. As the NSF report shows, there has indeed been an increase in the number of individuals born in Asia who are employed in S&E occupations in the United States. These include both individuals educated abroad and those who received their degrees in the United States and chose to stay. Since the largest numbers come from China and India these figures are also included in the table.

Table 6

Doctorate holders in US science and engineering occupations, by place of birth: 1990 and 2000

Place of birth	**1990**		**2000**	
	Number	**Percent**	**Number**	**Percent**
USA	159,000	76.1	240,000	62.7
EU-15	8,000	3.6	18,000	4.7
Asia	20,800	10.0	72,600	19.0
China	5,500	2.6	33,200	8.7
India	6,200	3.0	19,000	5.0
Indonesia	400	0.2	400	0.1
Malaysia	100	0.1	300	0.1

Philippines	400	0.2	1,200	0.3
Singapore	100	0.0	300	0.1
South Korea	1,300	0.6	4,700	1.2
Thailand	200	0.1	500	0.1

Source: NSF (2007) *Asia's rising science and technology strength*.

A country's S&E article portfolio reflects the relative emphasis placed on different fields. As the NSF report shows, the S&E article portfolio of Asia is more concentrated in the physical sciences and engineering/ technology than are the portfolios of the EU and United States. In 2003, these fields accounted for 60% of Asian-authored articles, compared with 40% of EU articles and 30% of US articles. Asia not only has a relatively smaller life sciences portfolio than the EU and the United States but also a smaller proportion of articles in the social and behavioral sciences.

Table 7

Portfolio changes in science and engineering articles, by country: 1988 – 2003 (Percentage point change)

Country	Physical sciences and mathematics	Life sciences	Engineering/ technology	Social/ behavioural sciences
Indonesia	4.9	-5.5	-0.6	1.1
Malaysia	10.8	-18.0	12.4	-5.2
Philippines	12.3	-13.9	1.6	0.0
Singapore	8.7	-19.2	15.4	-4.8
South Korea	-9.2	14.9	-4.2	-1.6
Thailand	12.9	-14.0	4.5	-3.3
EU-15	0.7	-4.4	2.0	1.7

Source: NSF (2007) *Asia's rising science and technology strength*

But these general trends sometimes mask interesting individual profiles and especially how individual countries have responded to human resource challenges in the field of S&T. We discuss briefly three examples: Malaysia, Pakistan and Singapore.

Human resources in S&T development lagging behind economic and industrial growth: The case of Malaysia.

The number of researchers in Malaysia stands at 18 researchers per 10,000 workforce (2002). This figure seems low when compared with that of developed countries, which average 80 researchers per 10,000 labour force. Although Malaysia fares better when compared with some of its Asian neighbours, Thailand, Philippines and Indonesia, our country review nevertheless argues that there are indications that Malaysia does face shortages of skills and capabilities in some areas. This is likely to be a constraint for Malaysia to develop a strong technology base. In cognisance of this shortfall, various initiatives have been made to continuously develop Malaysia's human resources, through provision of better access to training and re-training of human resources. On a similar note, the Government has also sought to improve programs to attract qualified personnel from abroad through its 'Brain Gain' programme. The Malaysian Government also introduced several initiatives to ensure that the workforce is given opportunity for training of the industrial workforce as well as the S&T workforce. The next 10 years will see a greater emphasis on human resource enhancement as availability of skilled and knowledge workers are a major pre-requisite to transform Malaysia from a production-based into a knowledge-based economy. Malaysia is likely to face shortages of highly skilled workers in the coming decade.

Innovative and successful strategies for human resource development

<u>Pakistan</u>

An example of an innovative initiative to fast-track the development of highly skilled workers is discussed in the country review of Pakistan where the Ministry of Science and Technology in 1985 launched a Human Resource Development Program. Over 1000 young scientists and engineers were sent abroad for higher studies. The cost of this programme was US$70 million. In order to promote indigenous technological development, the government established the Scientific and Technological Development Corporation (STEDEC) with US$ 1.16 million as seed capital to commercialize processes and products developed by R&D institutions. In addition, to promote research, the government established a Research and Development Fund. Scientists, engineers and technologists were awarded research allowance, computer allowance and PhD allowance in addition to the normal pay scales. In the Seventh Five Year Plan (1988-93), there was considerable enhancement of funds for S&T (US$522.26 million against US$430.89 million in the Sixth Five Year Plan (Government of Pakistan. 1982 and 1987).

Singapore

The Singapore case is a very good example of how a small Island country without any great natural resource endowments of the primary sector has industrialized over the last four decades through the development of technological capabilities in the manufacturing sectors of economy up to 1980s. Once the country begun to experience success through the application of knowledge, the government policies led to two major strategies of mobilizing intellectual capital by supporting higher educational institutions including public research institutions; and secondly by mobilizing global companies to invest in R&D and technology development and commercialization in Singapore since early 1990s. As these two strategies paid off by the late 1990s, the country further raised the level of science and engineering and management support through three major universities and their research centres to embark on science based innovation by targeting two major areas, namely biomedical engineering and information and communication technologies including telecommunications.

In 2004, there were a total of 18,935 research scientists and engineers (RSEs) and 3,705 fulltime postgraduate research students (FPGRSs) at the master degree and PhD levels. The country review report identifies as the unique feature of human resources of Singapore the way they identify researchers in R&D and the specific identification of engineers which they call research scientists and engineers. This illustrates the importance given to engineering and technology sciences compared to other countries in the Asian region. Engineering and technology constitutes a predominant proportion of the research workforce of Singapore, which is about 64% of the total including the post graduation population. 53% (9,968) of the RSEs had a bachelor degree, 26% (4,904) a master degree, and 21% (4,063) a PhD as the highest formal qualifications. 33% (1,215) of the FPGRS's were pursuing studies at the master degree level and 67% (2,490) at the PhD level. The number of RSE's per 10,000 labour force was 86.7. The number of TRSE's (i.e. RSE's + FPGRS's) per 10,000 labour force was 103.7. The private sector employed 61% of all RSE's; 80% of those with a bachelor degree as the highest formal qualifications; 58% of those with a master degree; and 19% of those with a PhD. The higher education sector employed 20% of all RSE's but 52% of those with a PhD. The public research institutes employed 10% of all RSE's and 23% of those with a PhD. The government sector employed 9% of all RSE's and 6% of those with a PhD.

3.5 Informal S&T structures and scientific communities

Informal S&T structures can flourish – or at least survive – in the smallest science systems. Nepal is a case in point. It has 74 professional societies, which are registered with the different District Administrations. The membership of the professional societies existing in Nepal is quite low; the majority of them have fewer than 500 members. By membership, the largest one is the Nepal Engineers Association and the Nepal Medical Association, which have memberships of 3578 and 2146, respectively. As far as journals are concerned, the country review shows that there are 37 local journals. These journals are published by various professional associations and specialized journals cover a specific discipline. Journals such as the *Journal of the Institute of Science and Technology*, Tribhuvan University and the *Nepal Journal of Science and Technology* launched by RONAST and Scientific World published by Ministry of Science and Technology publish articles from all disciplines of S&T. In terms of publications, Nepal is yet to register its presence at the international level. Much of its science publication output finds its way into its annual professional societies and journal established by these societies.

Pakistan

At the other end of the spectrum, one finds Pakistan which currently boasts 315 scientific journals and 24 scientific societies (Table 8 below).

Table 8

Science and Technology Journals and Professional societies of Pakistan, 2000

Areas/Fields	Journals*	Scientific Societies
Physical Sciences	13	2
Agriculture and Biological	69	8
Chemical Sciences	18	2
Engineering & Technology	73	2
Medical Sciences	56	3
General S&T Fields	86	7
Total	315	24

Source: Pakistan Council of Science and Technology, 2000

* includes Monthly issues

3.6 Knowledge production and *output*

We conclude this report with a comparative glance at the research output of the countries included in our review (excluding Nepal). Table 9 also includes comparable data for this period for China, India and Korea.

Table 9

S&T Publications from the Web of Science (SCI)

	1998	1999	2000	2001	2002	2003	2004	2005
Bangladesh	324	359	346	389	423	471	430	501
PR China	18833	23398	29004	33206	38469	46900	47306	56,524
India	16037	17104	15983	17501	18525	20803	20830	21,164
Indonesia	342	381	422	486	395	489	455	560
Korea	10458	11894	13200	15519	16642	20529	21939	23,004
Malaysia	798	869	814	922	934	1171	1254	1,586
Pakistan	601	577	596	531	691	763	903	1,060
Philippines	311	344	351	315	410	440	424	486
Singapore	2490	3046	3392	3802	4238	4846	5109	5,419
Sri Lanka	124	168	167	157	176	264	226	290
Thailand	935	1043	1185	1331	1591	2048	2047	2,543
Vietnam	239	249	322	356	346	497	412	573

The salient points that emerge from these comparative statistics are the following:

- With the exception of Singapore annual production of ISI articles is weak to neglible. This is also evident in Table 1 where the number of papers per million of the population is presented. On the lower end, the performance" of countries such as Bangladesh, Indonesia, the Philippines, Sri Lanka and Vietnam is both surprising and of concern. Although one should allow for the possible constraining effect that publication in mostly English journals might have, it is quite obvious that these countries are not doing enough to create incentives and support (basic) research at their universities.
- A more positive finding is evidenced by the steady increase in output in all countries under review. The smallest growth is documented for Indonesia, Pakistan and the Philippines. The most spectacular growth was recorded for China, Korea, Singapore and Thailand.

4. Concluding comments

- The ten countries in our review exhibit huge variation in S&T priorities and associated emphases in investment: From the agriculture and resource-based economy of Bangladesh (where investment in agricultural R&D predominates) to the manufacturing and high-technology industrialized economies of Singapore (and to a lesser extent Malaysia and Thailand).

- Very different science governance models: From the (socialist) model of central planning as evident in the heyday of Suharto's rule in Indonesia and still current in Vietnam (where the main institutions are modeled along the lines of the old Soviet Academy of Sciences) to the much more "liberal" approach associated with national systems of innovation models in Thailand and Singapore.

- The emphasis on and support given to the social sciences in these different science systems vary hugely. In the Vietnamese case, social science is afforded a central role (but within the constraints of a socialist model). In countries such as Singapore with its huge emphasis on SET, the social sciences are nearly invisible. This is also the case, but for very different reasons, in countries such as Bangladesh (dominated by agricultural R&D) and the Philippines (where the science system is generally in decline or at best in stagnation).

- The presence or absence of colonial rule (mainly British or Dutch) has influenced the state and strength of science in different countries differently. Although science in Indonesia has a long and rich history through early Dutch efforts, all of these were established and geared towards Dutch interests. Worse, local scientific facilities such as the famous botanical gardens at Borgor were used by Dutch scientists exclusively. No indigenous scientific capacity was developed with the result that with independence in the 1950s the country had to start anew with developing its own institutions and capacities in science. The British model of science, and especially the concept of a central council for scientific and industrial research (CSIR) was hugely influential in India (not included in our review) and hence also in Pakistan and Bangladesh.

- Some of the countries in our review have witnessed a fair degree of political instability over the past 50 years which in turn has had very negative impact on the science systems in those countries. Some of these related to lengthy periods of war (Vietnam) or civil war (Sri Lanka); others to significant regime changes (Suharto in Indonesia and more recently Musharraf in Pakistan).

- Two countries in our review stand out as examples of extraordinary industrial and economic growth: Malaysia and Singapore. Malaysia went the route of liberalizing its economy and encouraging foreign direct investment as much as possible. This has paid off and its sustained economic growth has led to a situation where it is now regarded as one of the most competitive countries in the world. However, its expenditure on R&D as percentage of GDP remains below 1% and although it has given increased attention to the fields of SET, its graduate output is still dominated by the SSH. All of this has created a situation where human resource development has becomes its biggest constraint and also challenge. Singapore, on the other hand, has converted its huge economic growth into substantive investments in R&D including in human resource development. Its most recent GERD/GDP of 2.6% is significantly above the EU average. As far as scientific field is concerned, there are huge investments in life sciences (microbiology/ stem cell research, human genomics and bioinformatics but practically nothing in the social sciences.

- Knowledge production as measured in terms of article output in ISI Web of Science is generally poor in our ten countries. Except for Singapore (which now produces more than 5000 articles per year in ISI journals), the output of the other countries (relative to their size) remain small (Pakistan, Malaysia and Thailand) to nearly insignificant (Bangladesh, Nepal and Sri Lanka). There is some evidence of a culture of privileging local journal support, especially in Pakistan and Nepal.

- The role of universities in knowledge production is equally variable. Not surprisingly some universities in Singapore (such as the National University of Singapore) have achieved international recognition. This is also true of some institutes in certain countries (e.g. in Pakistan – The Hussein Ebrahim Jamal (HEJ) Research Institute of Chemistry was established at the Karachi University). In most countries in our review, however, research at universities is limited mainly because of a lack of sustained investment in

R&D and small numbers of post-graduate students which in turn is linked to the small proportion of staff with doctoral degrees themselves. This situation is found both in highly industrialized countries such as Malaysia and increasingly Thailand as well as in countries such as Nepal, the Philippines and Sri Lanka. It is, therefore, not surprising that the development of highly skilled human resources remains the single biggest challenge for many of these countries. It is somewhat surprising that few (if any) of the countries reviewed adopted performance-based incentive schemes as a human resource development strategy. The preferred model was one which sent and supported students to study in the USA with some conditions about returning to their home country.

- Within the domain of S&T policy development, interesting differences have been documented. In most countries in our review, systematic attention to the development of a national science and technology policy document only commenced after independence and usually only in the 1970s and 1980s. In the Singapore and Malaysia cases, science and technology policy development was intimately linked to industrial policy development. To some extent this is also the case, somewhat later, for Thailand who has adopted the notion of a national system of innovation in its own science policy development process. Other countries with a much clearer socialist economic legacy – such as Vietnam and Indonesia (and Pakistan under Bhutto) – incorporated science and technology policy issues within the framework of centralist economic planning. This usually meant that S&T was only fore grounded in the 1980s within the 3rd or 4th cycles of economic planning.
