Innovations in Pakistani Universities, R & D Centres and Corporate Research Institutes

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Abstract Research and development (R&D) comprises creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications.

Universities carry out R & D from teaching and other work-related activities.

Corporate research institutes have Researchers which are professionals engaged in the conception or creation of new knowledge, products, processes, methods and systems and also in the management of the projects concerned. And they have Other supporting staff which includes skilled and unskilled craftsmen, secretarial and clerical staff participating in R&D projects or directly associated with such projects.

Innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations. Innovations are measured through science as an activity (R&D, design, acquisition of machinery, technology, and training) and an output (introduction of product or process innovation). The indicators of the innovation in Universities, R & D centers and corporate research institutes are as follows:

Input indicators (R & D Expenditure and Human Resource)

Output indicators (Publications, No. of PhDs, processes developed, improved or indigenized and patents)

Impact indicators (Innovation or ratio of expenditure on R & D)

Key words innovations, R&D, corporate research institutes

1 Intruduction

1.1 Focus of Research

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. Pakistan inherited a small scientific and technological infrastructure at independence. The paper is an attempt to collect study and analyze the innovations at Pakistani Universities, R&D centers and corporate research institutions since independence.

1.2 Significance of Research

This research draws awareness towards the development of Universities, R & D organizations and institutes in Pakistan over time which will help in the overall development through higher productivity, manufacturing, education rate and increase in patents granted.

Another significance of this research is the recommendation of new initiatives and plans for an innovative culture in Pakistan based on the study of quantified and qualified data on innovations that already exists.

1.3 Literature Review

1947-1950

In 1947 there was just one functioning university, three small laboratories and one Agriculture College, research institute. In 1949, Pakistan Patents Office was developed in Karachi. 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.[1]

1951-1960

The Pakistan Medical Research Council was also established in 1953 and the Atomic Energy Research Council in 1956. The first National Commission on Science and Technology was constituted in 1959. Pakistan Standard Institute was established in 1951 which has been given statutory status in 1961. In 1964 a Scientific and Technological Research Division was created in the federal government

to co-ordinate the implementation of national S&T policy. The National Science Council was set up in 1962 to advise the government on all policy matters and to co-ordinate the work of research organizations. In 1963 the Defense Science and Technology Organization (DESTO) was set up followed by the establishment of Irrigation, Drainage and Flood Control Research Council and Council for Works and Housing Research in 1964. In 1965 the University of Agriculture at Faisalabad and the University of Engineering and Technology at Lahore were established. [2]

1961-1970

During the period, 1960-1970 Pakistan made some progress in terms of establishing an infrastructure for science and technology. Almost 150 R&D organizations and 19 universities began functioning. The Pakistan Institute of Nuclear Science and Technology (PINSTECH) was founded in 1963 as the flagship R&D institution of the Pakistan Atomic Energy Commission (PAEC). The Centre for Mineral Exploration was established in 1961 in Lahore. [3]

1971-1980

In 1972 Ministry of Science and Technology was created and Minister of Science and Technology was included as member of Executive Committee of the National Economic Council (ECNEC) and 14 research organizations were placed under its administrative control.

In 1976 first draft Science and Technology policy was submitted to the Cabinet which was approved by Government in 1984. In 1976 13 protocols involving more than 250 cooperation activities on science and technology with China got implemented. Fourteenth protocol involving 36 collaborative projects with China got implemented in 1997 for exchange of technology. Pakistan Science Foundation was established in 1973. National institute of electronics was established in 1979. In 1975 a Science Policy Cell was established in the Ministry of Science and Technology to initiate action on formulation of an S&T Policy. Nuclear institute for Agriculture and Biology was established in 1978. [4]

In collaboration with United Nations Industrial Development Organization in 1975 a project named as Metal Advisory Service was initiated. In 1995 it was renamed as Metal Industry Research and Development. [5]

1981-1990

In 1984 MOST launched its HRD programme. In 1988 COMSTECH Secretariat was established in Islamabad. In 1980-1989 an Action Plan for Science and Technology Policy was proposed. In 1984, 110 technical colleges were running and total enrollments in these were 27372. In 1981 three protocols on science and technology with Turkey had been implemented. National institute of Silicon Technology was established in 1981. Centre for applied molecular biology (CAMB) was established in 1983. National Commission for Science and Technology (NCST) was established in 1984. In 1985, the Ministry of Science and Technology, realizing the need for high-level skilled work force, 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. 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). Although allocation of funds for S&T increased their utilization rate declined from 80 percent in the Fifth Five Year Plan (197883) to 15 percent in the first three years of Eighth Five Year Plan (1993-88). [6]

In 1981 total citation of Pakistani papers were 183. Pakistan's share in world's authorship was 0.04 percent. [7]

1991-2000

In 1992 Cabinet constituted a Committee on Science and Technology to review and coordinate R & D efforts. In 1994 National Technology Policy and Technology Action and Development Plan was approved with Rs.2.8 billions budget. MOST initiated 47 projects under this Action Plan. In 1996 R & D organizations were reviewed by a High Level Review Committee (HLRC) headed by Mr. Munir Ahmed Khan. By 1998, 32 universities and degree awarding institutes in public and private sector were developed among which only QUAID I AZAM University was meant for post graduate research and nine center of excellence were set up. 155 major R & D organizations were developed in which 41% were working in field of Agriculture. At Federal level these were administered by 13 controlling agencies. In 1992, 240 technical colleges enrolled 34589 students. 26 projects on science and

technology with Kazakhstan got implemented in 1996. Four science and technology protocols with South Korea got signed in 1995. [8]

In 1956 Pak-Swiss Training Centre was developed in Karachi. [9]

In 1994 total citation of Pakistani papers were 499. Pakistan's share in world's authorship was 0.08 percent. [10]

National university of science and technology (nust) was established in 1991. NIT Risalpur has worked on the recycling of asphalt pavements which being mega project of NUST, MSU USA has been jointly working with NIT. Recently NIT had been funded 8 Million dollars on the successful research of RCC pavements. NUST has also executed numerous beneficial projects in other disciplines. [11]

2001-2006

Our literacy rate estimated as 39 percent. Only 7 percent of the 16-17 age group are enrolled at the higher secondary level and 2 percent of the 18-23 age group are enrolled at the university level. About 98 percent of our youth do not have access to higher education. All Pakistani Universities and Center of Excellence collectively produced 918 PhDs. There are about 110 professional colleges. 1170 scholars were sent abroad. Out of these 740 returned, 581 got employed and rest were jobless which left the country. Total no. of R & D manpower is 14500(2005). Total of 2528 PhDs are in science subjects out of which 25% work in research. Total of 35000 patents registered by Pakistan Patent Office and only 35 percent of these are for engineering sciences. Few science and technology protocols have been signed with Iran, Egypt and Romania. CAMB has been dealing in DNA technology, a total of 186 thalassemia patients and 372 beta thalassemia patients have been analyzed by CAMB. [12]

PCSIR has developed 500 processes but only 150 processes have been absorbed by the local industry. PCSIR has published 4000 papers and 110 scientists received PhDs degrees from universities in Pakistan undertaking research at PCSIR research laboratories. [13]

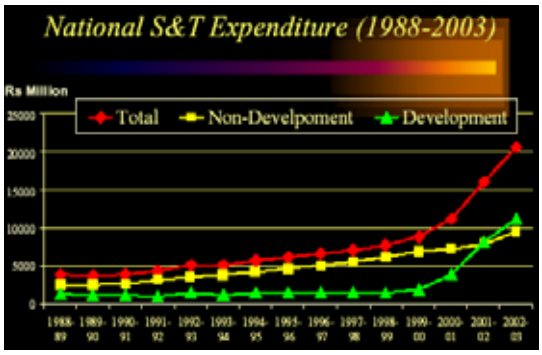
Pakistan Council for Appropriate Technology installed 200 mini hydel plants in NWFP with total generation capacity of 2 MW and set up 60 cottage level industrial units. [14]

National Physical and Standards laboratory has been working on World Solar programme 1996-2005 which comprises of 300 projects on renewable energies. [15]

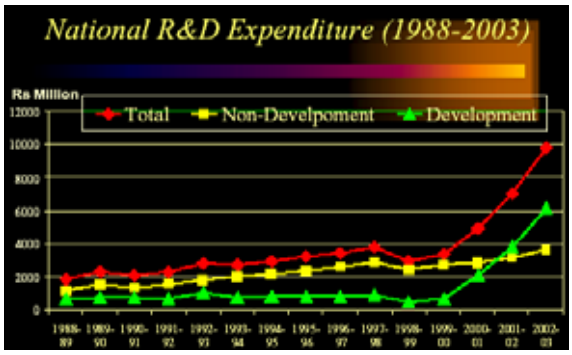
HMC Taxila and Pak-Swiss Training Centre Karachi train manpower in CAD/CAM and CNG machines. Pakistan Computer Bureau and MOST train scientists in R & D. [16] Much of the R&D expenditure goes to agriculture and fisheries, industrial research, defense, health and engineering and technology.

2 Input Indicators of Innovations in Universities and R & D in Pakistan

The following graphs show the trends in the national science & technology and R & D expenditures from 1988 to 2003, which act as inputs to the innovation process.



Source: PCST



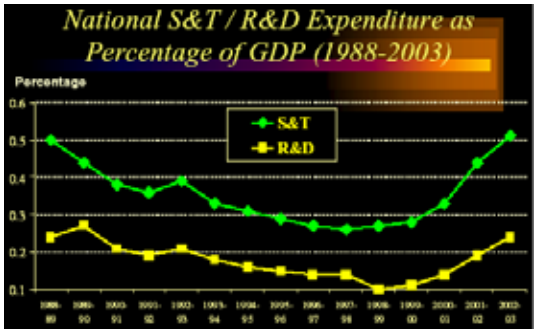
Source: PCST

Other areas are very thinly supported as shown in Table 1.

Table 1 Field wise distribution of R & D expenditure (US $ Millions)

Field	1998-99	1999-00	2000-01	2001-02
Agriculture and Fisheries	23.19	25.52	27.69	29.94
Health	1.91	1.94	1.22	2.14
Engineering and Technology	1.30	3.72	1.25	3.14
Industrial Research	4.13	4.52	4.46	9.01
Forestry	0.89	1.19	0.98	0.98
Telecommunication	0.36	0.41	0.41	0.36
Housing and Works	1.41	1.55	1.58	0.44
Energy	0.65	0.66	0.68	0.70
Irrigation &Water Resources	0.48	0.53	0.50	0.47
S&T Policy	0.10	0.11	0.57	0.61
Defence S&T	1.61	1.88	2.03	2.73
Transport & Communications	0.18	0.17	0.33	0.24
Metrological Sciences	0.06	0.06	0.07	0.07
Ocean and Marine Sciences	0.207	0.208	0.246	0.233
Total	37.42	43.56	43.26	52.46

Source: "The Islamic Republic of Pakistan" by V.V. Krishna and S.T.K. Naim 2005



Source: PCST

3 Output Indicators of Innovations in Universities and R & D in Pakistan

According to Pakistan Scientific and Technological Information Centre, about 357 periodicals related to scientific subjects are published annually. Out of these only 100 are published regularly. Table below shows the number of journals and societies in different disciplines.

Science and Technology Journals and Professional societies of Pakistan, 2000

Areas/Fields	Journals*	Scientific Societies
Physical Sciences	13	2
Agriculture and Biological	89	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

The total number of publications appearing in the 8,000 leading journals indexed in the Web of

Science arising out of Pakistan in 2005 was 1,259 articles, representing a 41% increase from 2003, and a 60% increase since 2002. The research output from the Universities themselves showed a dramatic increase over the same period, from 460 articles in 2001 to 1039 in 2005, representing a 126% increase.

The contribution of the higher education sector relative to that of the indigenous R&D sector also demonstrated a marked increase. The table below demonstrates the annual increase from 2001-2005.

YEAR	Research Output (Articles Published)	
	Pakistan (Total)	Universities/DAIs
2001	636	460
2002	788	576
2003	890	639
2004	1048	781
2005	1257	1039

Source: HEC website accessed on 4-5-2008

Subject Category	Number of Publications	% of Total
Plant Sciences	543	13.7
Chemistry, Medicinal and Multidisciplinary	726	18.3
Biochemistry& Mol. Biology	199	5
Pharmacology & Pharmacy	195	4.9
Chemistry Inorganic & Nuclear	183	4.6
Nuclear Science and Technology	175	4.4
Others	na	na

Field Wise Publications from Pakistan

Source: Based on ISI web of science database 2005

S&T Manpower (2004) [18]:

- 12,820 degree holder scientists / engineers
- 88 scientists / engineers per million population
- 23 PhDs per million population
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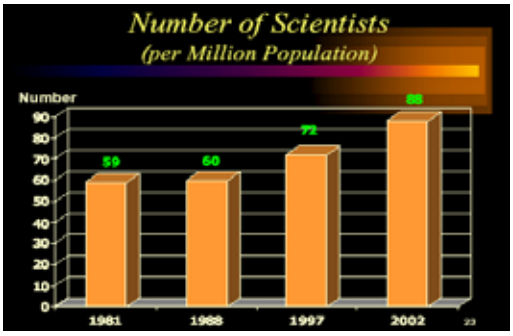
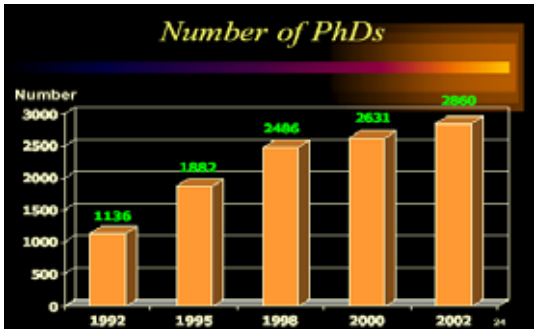
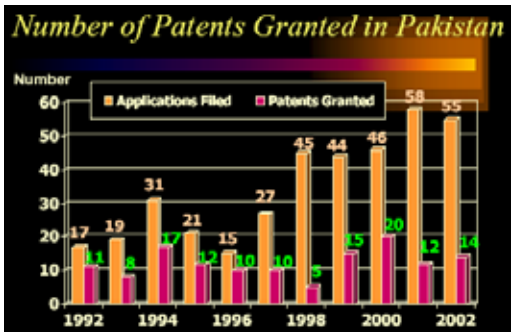


Source:PCST



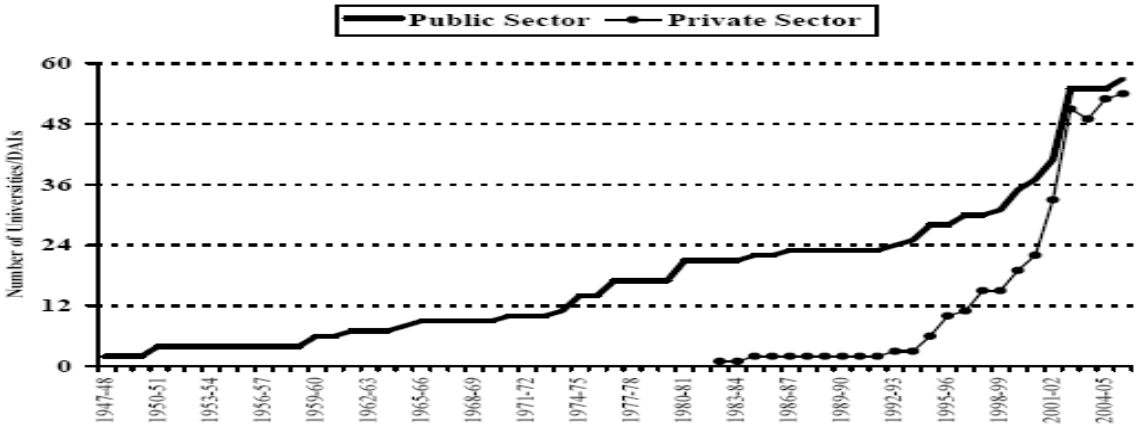
Source: PCST



Source: PCST

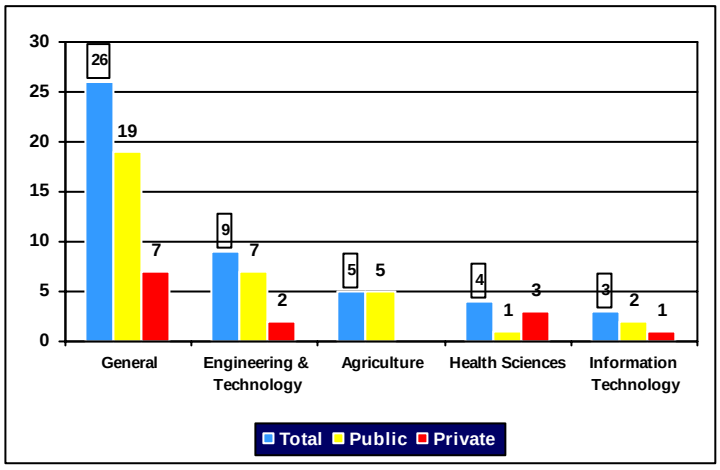
PATENTS GRANTED[19]:
2005 390
2006 247

UNIVERSITIES
There was a sharp increase in the number of universities, both in public and private sector after 1995-96 as shown below:



Source: Higher Education Commission website accessed on 18-4-2008

The sector wise distribution of the Universities is as follow:



Source: Pakistan Council for Science and Technology 2006

Total No. of Universities in 2007 is 125.

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. As indicated by Tables 3 and 4, there are about 8395 faculty in the private and public universities in Pakistan. While only 12% of the staff in private universities has PhD degrees, about 30% of the staff in public universities has PhD degrees. 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. [20]

Field of study	PhD	M.Phil	Masters	Bachelors	Total
Agriculture	Na	Na	Na	Na	Na
Engineering	40	4	55	82	181
Environmental Science	1	-	-	-	1
ICT	106	27	602	122	857
Medical Pharmacology	65	340	297	483	1185
Natural Sciences	66	42	116	51	275
Total	137	32	832	78	1079

Field of Study and Qualification Distribution of Faculty Strength in Private Sector Universities

Source: Higher Education Commission (2000)

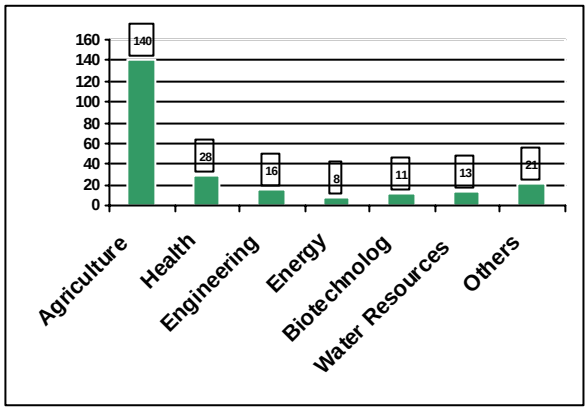
Field of study	PhD	M.Phil	Masters	Bachelors	Total
Agriculture	393	85	303	24	805
Engineering	261	53	415	421	1150
Environmental Science	24	5	34	4	67
ICT	45	12	304	74	435
Medical Pharmacology	166	91	125	147	529
Natural Sciences	771	247	936	22	1976
Total	2172	655	3740	749	7316

Field of Study and Qualification Distribution of Faculty Strength in Public Sector Universities

Source: Higher Education Commission (2000)

R &D INSTITUTES

Sector-Wise No. of Major R&D Institutions



Source: Pakistan Council for Science and Technology 2006

INSTIUTE/ORGANIZATION	TOTAL MANPOWER (SCIENTISTS AND TECHNOLOGISTS)	NO. OF PHD'S
Pakistan agriculture research council	644	184
Ayub agricultural research institute, faisalabad.	717	77
Cotton research institute, multan	40	4
Nuclear institute for agriculture and Biology (niab)	200	22
National institute of biotechnology and genetic engineering (nibge), faisalabad	58	21
Biomedical and genetic engineering laboratories,	19	5
Pakistan council for scientific and industrial research	607	97
Heavy mechanical complex ltd. Taxila	350	100
Pakistan council for renewable energy technology	85	8
Hydrocarbon development institute of Pakistan (hdip)	46	5
Pakistan medical research council (pmrc)	59	13
National institute of health (nih)	110	7
Optics laboratories, Islamabad	294	Not

Source: PCST 2004

4 Innovations of R&D Institutions

- PAKISTAN AGRICULTURE RESEARCH COUNCIL
- 213 Varieties of crops developed and released under National Coordinated Research Programmes:
- Wheat: 63; Rice: 26; Pulses: 23; Oilseeds: 15; MSM: 16; Sugarcane: 21; Fodder: 10; Fruits: 30; Vegetables: 07; Potato: 02
- Introduction of 100,000 bee colonies - 1,400 tones annual honey production.
- 3 fold increase in milk production.
- Increase in livestock reproduction form 1 to 4 off springs through embryo transplant technology.
- Production of disease and virus free seed potato through tissue culture.

- AYUB AGRICULTURAL RESEARCH INSTITUTE, FAISALABAD
- Varieties of crops developed:
- Rice: 50; Cotton: 11; Oilseeds: 13; Wheat: 14; Sugarcane: 15; Vegetables: 44; Fruits: 51; Pulses & Legumes: 22; Maize & Millets: 31; Fodders: 14.
- COTTON RESEARCH INSTITUTE, MULTAN
- Developed 7 high yielding, early maturing, tolerant to heat and disease varieties of cotton.
- Management of cotton pests through identification of plant cultivars.
- Identification of cultivars tolerant to heat stress and biological control agents.
- Developed transgenic cotton "Bt Cotton" through transferring a gene form soil bacterium .
- AGRICULTURAL RESEARCH CENTRE, TANDOJAM
- Development of high yielding improved fiber quality Wheat ' Chandi-95'.
- NUCLEAR INSTITUTE FOR AGRICULTURE AND BIOLOGY (NIAB)
- Development of 'NIAB-78' cotton variety cotton production increased from 2 million to 10 million bales.
- Evolution of 29 varieties of cotton, rice & food legumes through Mutation Breading.
- Development of Saline Agriculture Technologies.
- CENTRE FOR ADVANCED MOLECULAR BIOLOGY (CAMB), LAHORE
- Produced genetically modified pest resistant varieties of rice, cotton and chick pea.
- Discovered 45 new restriction enzymes.
- Pioneered DNA-based methods for pre-natal diagnosis of beta thalasemia.

- Developed methods for early detection of tuberculosis, hepatitis and breast cancer.
- NATIONAL INSTITUTE OF BIOTECHNOLOGY AND GENETIC ENGINEERING (NIBGE), FAISALABAD
- Development of Transgenic Cotton for virus resistance.
- Production of Biofertilizers.
- Research on use of bacteria in extracting minerals and fossil fuels.
- PCR based diagnostic of infection diseases.
- Developed and applied methods of effluent detoxification and waste management through use of microbes.
- BIOMEDICAL AND GENETIC ENGINEERING LABORATORIES, ISLAMABAD
- Identified 20 genes and loci responsible for blindness, deafness and other disorders in families.
- Pioneered following techniques:
- Stem cell culture and flow cytometry
- DNA based diagnosis of bacterial and viral disease
- DNA based paternity and forensic analysis
- Developed largest bank of human cell lines
- Tabulation of transplantation antigens (HLA) assisting surgeons in organ transplantation.
- CENTRE FOR ANIMAL BIOTECHNOLOGY, VETERINARY RESEARCH INSTITUTE, PESHAWAR
- Developed new vaccine "Oil Adjuent HS Vaccine" against bacterial disease of ruminants, increasing immunity time of cattles and buffaloes from 2-3 to 15 months.
- PAKISTAN COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH (PCSIR)
- Developed 648 processes.
- 360 patents registered including 29 foreign patents.
- Published 3750 papers in local and international journals.
- Capability of setting up small and medium scale production units.
- 250 processes leased out to private and public sector.
- 150 processes available for commercialization.
- HEAVY MECHANICAL COMPLEX LTD. TAXILA
- Attained capability to design, engineer and manufacture machinery for turn-key supply of sugar and cement plants and equipment upto 12000 TCD and 4000 TPD capacity respectively.
- Achieved to-date more than 70% deletion in sugar plants.
- Developed and supplied spares for Pakistan Steel.
- HEJ RESEARCH INSTITUTE OF CHEMISTRY, KARACHI
- Has the largest Ph.D. level research programmes in the country.
- Producing 30-40% of science Ph.Ds in the country.
- 43 Ph.Ds and 8 M.Phils produced during 1997-2000
- Developed large number of new products and processes.
- Processes commercialized include:
- The first synthesis of anticancer drug (Vinblastin)
- Enzymes for softening of leather, detergents, emulsifiers
- Discovery of large number of novel bioactive substances from medicinal plants including: anti-diabetic, anti-aids, anti-cancer, anti-pertensive, anti-inflammatory, analgesic, anti-platelet aggregation antibiotics and anti-fungal agents.
- Research publications (1997-2000) 67 books, 1450 research papers in international journals.
- PAKISTAN COUNCIL FOR RENEWABLE ENERGY TECHNOLOGY (PCRET)
- Capability to produce solar cells.
- Working towards manufacturing capacity of 40 kwp of crystalline photovoltaic cell.
- Development of solar appliances such as:

- solar water heaters; solar fruit and vegetable dryers; solar water distillation stills; solar cookers; solar room heating systems.
- Designing and installation of over 250 'run of river' type microhydel power plants ranging from 5-50 kw in the northern areas of the country.
- HYDROCARBON DEVELOPMENT INSTITUTE OF PAKISTAN (HDIP)
- Use of environmental friendly compressed natural gas (CNG) in road transport.
- HDIP research findings helping oil and gas exploration activities in the country.
- PAKISTAN COUNCIL OF RESEARCH IN WATER RESOURCES (PCRWR)
- Developed and promoted indigenous technologies in the fields of Irrigation and Water Loggings.
- Over 200,000 acres of saline land reclaimed using tile drainage technology.
- PAKISTAN MEDICAL RESEARCH COUNCIL (PMRC)
- Established 19 research centres in different medical institutions.
- Completed over 153 research projects since 1994.
- Identified and worked on National Health Problems from 1976-90.
- Published over 2000 original research papers and 29 technical reports and monographs.
- Based on National Health Survey published "Health Profile of the People of Pakistan".
- NATIONAL INSTITUTE OF HEALTH (NIH)
- Active involvement in research areas of:
- Production and quality control of vaccine and sera
- Quality Control of Drugs
- Nutritional research
- Communicable disease
- Developed capability of manufacturing vaccines locally (Measles, Typhoid etc).
- Launched expanded immunization programmes covering 70 percent of the population.
- OPTICS LABORATORIES, ISLAMABAD

• R&D

- Laser Spectroscopy of Atoms & Molecules
- Precision Position Monitoring Systems for Detectors in CMS Project at CERN, Geneva
- Electronics Systems
- Optical Systems and Components

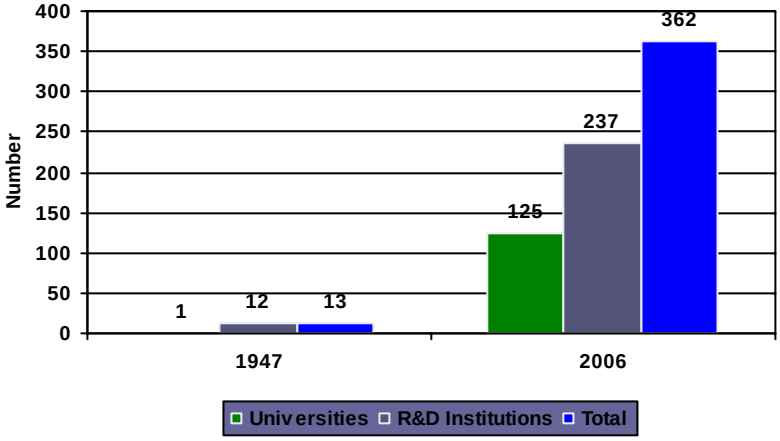
• Teaching

- Ph.D. Supervision of students from universities
- Project work for students in Engineering and Physics (B.Sc. and M.Sc.)

• Production (US $ 30m in 10 years)

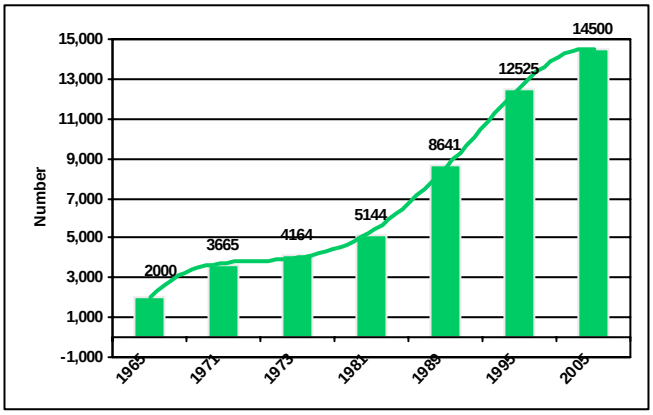
- Laser Land Levelors, Distance Measuring Devices Laser Crystals & Optical Components.

Growth of R&D Establishments



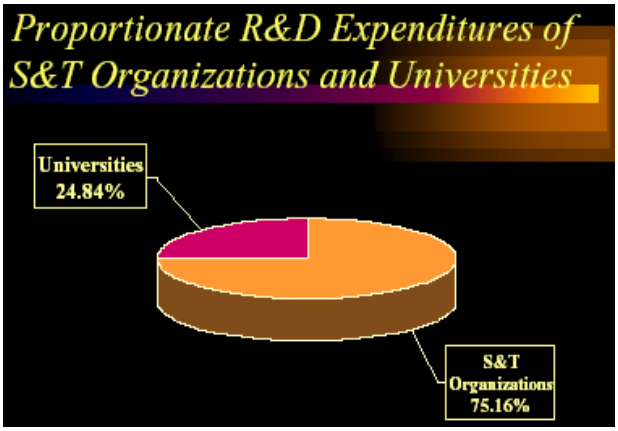
Source: Pakistan Council for Science and Technology 2006

Growth of R&D Manpower



Source: Pakistan Council for Science and Technology 2006

5 Impact Indicators/Ratio of Science and Technology go R & D and Universities in Pakistan



Survey/Date Collection

A questionnaire was used as a data collection tool on innovations in universities, R&D centers and corporate research institutes. The sample size was 7,5 and 12 respectively. The methodology also included online questionnaires and telephonic interviews.

6 Results & Discussions

Qutionnaire Esponse (First Four Questions)

UNIVERSITIES (Sample Size=7)

Institutes	A	B	C	D
	None	0-5 Mlln	5-10 Mlln	>10 Mlln
R & D Expenditures	28%	**57**%	15%	-
	None	1-50	51-100	>100
R & D Personnel	28%	**72**%	-	-
	None	1-10	11-10	>20
Yearly publications	**57**%	28%	15%	-
	None	1-5	6-10	>10
Registered patents	**86**%	14%	-	-

Corporate R&D Centers (Sample Size=12)

Institutes	A	B	C	D
	None	0-5 Mlln	5-10 Mlln	>10 Mlln
R & D Expenditures	**58**%	25%	17%	-
	None	1-50	51-100	>100
R & D Personnel	**58**%	42%	-	-
	None	1-10	11-10	>20
Yearly publications	**75**%	17%	-	8
	None	1-5	6-10	>10
Registered patents	**75**%	25%	-	-

R&D Institutions (Sample Size=5)

Institutes	A	B	C	D
	None	0-5 Mlln	5-10 Mlln	>10 Mlln
R & D Expenditures	-	-	20%	**80**%
	None	1-50	51-100	>100
R & D Personnel	-	-	-	**100**%
	None	1-10	11-10	>20
Yearly publications			20%	**80**%
	None	1-5	6-10	>10
Registered patents	40%	**60**%	-	-

The national expenditure on R&D is still considerably low, resulting in fewer amounts of scientists and engineers. Another big challenge out of the situation is that Pakistan has an extremely limited private sector R&D and innovation activities. There is a weak university-industry linkage, and a high volume of brain drain. The Pakistani R&D lacks competitive edge in the market and lacks the capacity to transform knowledge into products. Most of the universities and R&D centers of our sample have linkages with foreign organizations/universities for the purpose of training and R & D and very few introduce new processes/products annually. Almost 80 % of the respondents are not offered training at their workplace. A general trend for collaborating with the government for innovation is seen. Lack of funds is a major obstacle to innovations in Pakistan. Almost 50% of the respondents have their Quality Management System in place and are ISO certified.

Pakistan has a low literacy rate of 45.70% with male 59.8% and female 30.6 % (2003). There are 109 universities and degree awarding institutions with 730 affiliated colleges of higher education and about 60 major R&D organizations functioning in the public and private sectors. Almost 70% of the public/private institutions of higher learning are new and are in the process of establishing their research infrastructure. Pakistani scientists have contributed just 7832 papers in international journals during the period 1995-2005. Highest numbers of papers are published in the field of chemistry followed by plants sciences and biotechnology. Relatively more papers are published in collaboration with scientists in USA and UK.

Among the ten productive institutions the University of Karachi tops the list with (1222 research papers). This is followed by the Quaid-e-Azam University (1165 research papers) and the Agha Khan University (657 research papers) published in past ten years. The research productivity trend shows an average of 806 research papers contributed per year and a positive growth beginning from the year 2002. This is a result of wide ranging reforms of the higher education system and financial incentives provided by the government for promotion of research activities.

Detailed Analysis of Survey/Collected Data

INPUT INDICATORS

The analysis of the survey/collected data is attached as annexure A

INPUT INDICATORS

The analysis of the survey/collected data is attached as annexure B

7 Conclusions and Recommendations

Despite of financial constraint Pakistan is ready to increase investments in science and technology. Presently emphasis is being given to human resources development through training and to upgrading the existing R&D infrastructure.

Much of R&D in Pakistan is undertaken by the country's public universities and research institutes. Gross Expenditure in Research and Development (GERD) is invested mostly by the government, the private sector playing only a small part. In Pakistan, S&T has witnessed unprecedented support from government. The most notable increase in R&D expenditure is on higher education, which grew nearly fourfold from around 530 to 2 000 million Rupees. In this connection, it is interesting to note that Pakistan's National University for Science and Technology has figured in the top 500 universities in the world. The main focus areas have been: agriculture, health, engineering, defense, 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 per million populations.

The following are recommended after the research carried out:

- New knowledge, particularly knowledge related to technology, drives the economic systems. Economic agents, including firms and governments, are forced to adapt to technical change in order to survive in a competitive environment. While governments should act as facilitator, technology capabilities must accumulate in enterprises. This will only be possible if we strengthen our universities and R&D organizations and create effective linkages between them and industry. Our ability to compete or survive in the globalization of economic systems depends on our commitment towards the development of our human capital and ensuring a continuous learning process within the government institutions and enterprises to create a culture of innovation.
- Innovation is concerned with enhancing national productivity and national competitive performance. Dynamic innovation systems involve an inter-play between a number of different parts of the society which include the government, private sector, universities and research institutions. The transition of our economy from an agriculture-based economy to a knowledge based economy involves a mosaic of complex interactions in which a large number of players would be involved. The universities will need to play a central part in this transition through knowledge creation, its use and diffusion of new knowledge into the society through establishment of technology parks, business incubators, access to venture capital and other such schemes.
- We need to create knowledge networks through collaboration of government research laboratories and industry at the regional, national and international levels. Regional knowledge networks can be developed through collaboration of industrial clusters with the local universities.
- The higher education and S&T policy be targeted towards creating an innovation culture. It will be through our indulgence in innovation that will determine our comparative strength and ability to compete in the world markets. Innovation is not just creation of new products but also relates to changes in value addition and productivity increase brought about through skill development and technology, efficient management of production and services and their marketing.
- Promote scientific research in academic and research institutions in the country, thereby creating a research environment which attracts the brightest of our youth to take up careers in science and technology. For this purpose Higher Education Centers and Institutes should be established and maintained as world class Centers of Excellence in key disciplines so that they can contribute to the development of cutting edge science and technology in the country and where the youth of the nation can feel the excitement of extending the current frontiers of science to new horizons.
- Provide incentives to Firms (tax incentives, low interest loans, others) for setting up of in house R&D centers and for continuous training of their workers.
- Promote collaborative research between public R&D organizations/universities and private firms through supporting joint technology related projects and by encouraging mobility of scientists from universities/R&D organizations to promote private companies.
- Give special emphasis on the transformation of science and technology research output to new products and processes through access to Venture Capital and Technology Development Fund.
- Establish research institutes staffed with scientists and economists entrusted to carry out research on several aspects of policies related to technological capability building. This institute should regularly carry out Foresight studies identifying niche areas for development.
- Strengthen basic sciences and establish linkages with applied sciences such as agricultural sciences, engineering sciences, material sciences, information technology, biotechnology, pharmaceuticals and space sciences.

- Strengthen the Intellectual Property Rights regime in order to foster creativity and protect the rights of inventors.
- Support multidisciplinary research so that new scientific knowledge can be closely inter-linked between various disciplines and translated into economic benefits.

"The ability to translate the knowledge into products is the key to an innovative culture"

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