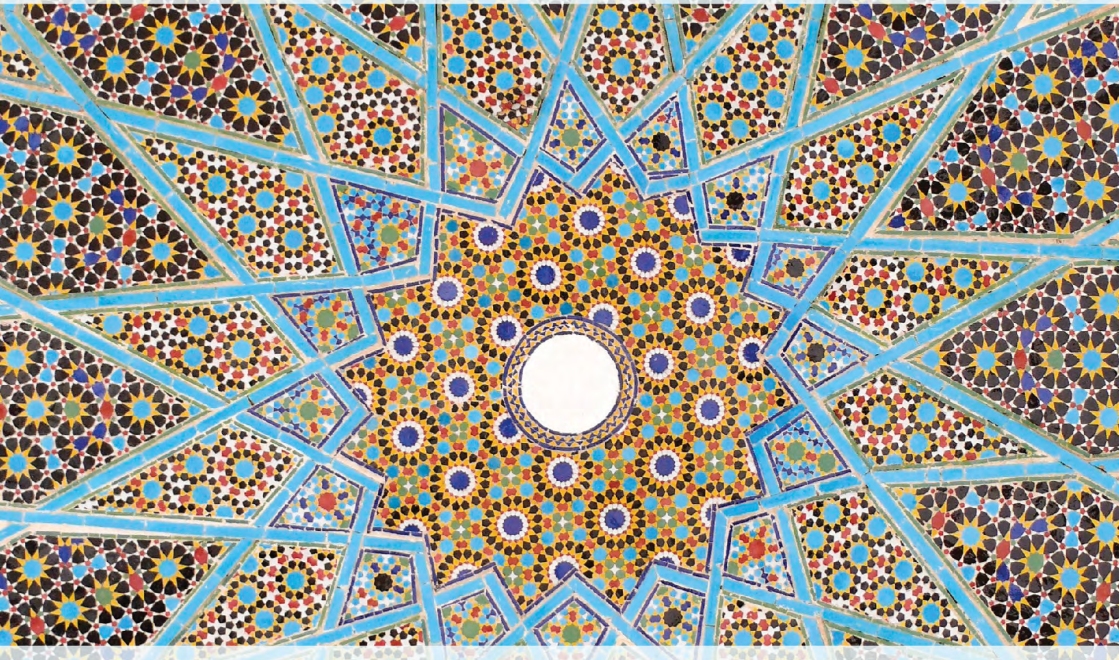
Pakistan Science and Innovation Review 2015



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Contents

Introduction and Summary

Modelled on similar analyses of China, India, South Korea and Brazil[1], as well as Malaysia, Jordan, and Egypt, this report provides an accessible and practical snapshot of science, technology and innovation (STI) in Pakistan. Science represents the act of discovery and invention and creation of knowledge that primarily takes place in universities, as well as public and private research laboratories. This report takes a broad view of science that includes natural and engineering sciences and technology as well as health and social sciences. Innovation is the commercial and social exploitation of the results of scientific research that primarily takes place in industry and through the process of entrepreneurship. Innovation can be one of six kinds, namely, science-based innovation, technological innovation (e.g. reverse engineering), process or product innovation, new markets, organisational or business model innovation, and social innovation. This report assesses the health of linkages between science and innovation in Pakistan and provides policy recommendations.

The primary purpose of this report is three-fold, namely, first, to serve as a snapshot and landscape of science and innovation activities and trends that are happening within Pakistan; second, to critically evaluate broad and narrow policy environment affecting science and innovation and make recommendations for its improvement; and third, to identify areas of good practice and promise as well as opportunities and gaps that various actors - internal and external - may seek to collaborte with, act upon, or replicate.

The story of Pakistan's science and innovation could be better understood by looking at it in a systematic way as a result of a complex set of factors and influencers (internal and external), policy choices driven – in part – by these influences, working and inter-relationships of various policy-making and implementing institutions, among others. It is important to appreciate the various elements that form the overall environment in which the public policy and science technology and innovation (STI) infrastructure interplay to understand the evolution and performance of a country's science and innovation system.

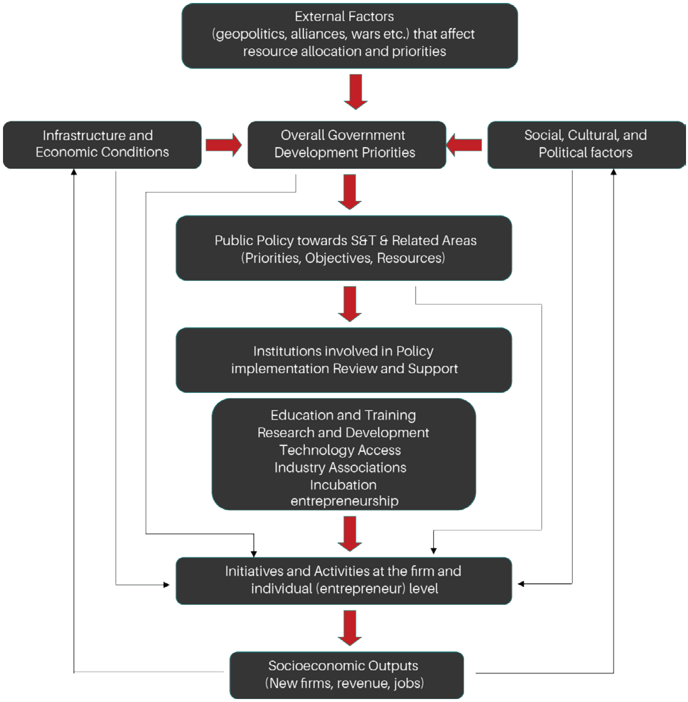

Figure 1: Public Policy environment for Science and Innovation: A Framework for analysis

Figure-1 provides a simplified snapshot of these influences. The figure illustrates the importance of taking into account seemingly irrelevant factors such as socio-political influences (e.g. prevalent social norms like sources of power and respect, family structure and its dynamics, and culture as well as political alliances, global power plays) as well as state of economic conditions and infrastructure (e.g. health, education, transportation, communications, property rights) in the society.[2] The overall development priorities of the society must inform the public policy regarding STI including the priorities, objectives, and resource allocation to scientific, technological, and innovative activities across various sectors. The role of a number of institutions in implementing the policies as well as efforts and aspirations of other institutions and (entrepreneurial) individuals then come into play. The linkages between these factors-influencers are critical (double arrows describe primary influences and single arrows describe secondary and tertiary influences) and their quality drives the quality of socio-economic outcomes from the system. The above graphic thus forms a framework through which analysis in this report can be coherently organised. The various chapters neatly fit the various boxes in this figure such as external factors (chapters on mapping, sustainability and collaboration), public policy and government priorities (chapters on mapping and recommendations), infrastructure and economic conditions (chapters on places and business), socio-cultural and political factors (chapters on mapping, places, and culture), and institutions and individuals (chapters on mapping, people and business).

The Challenge of Governance and Implementation

The greatest challenges in Pakistan are probably as much of the scientific variety as they are of governance and implementation. Time and again over the country's history – whether it is the green revolution of the 1960s and 70s or the nuclear programme of the 1970s and 80s, or the missile programme of the 1990s – Pakistani scientists and engineers have proven

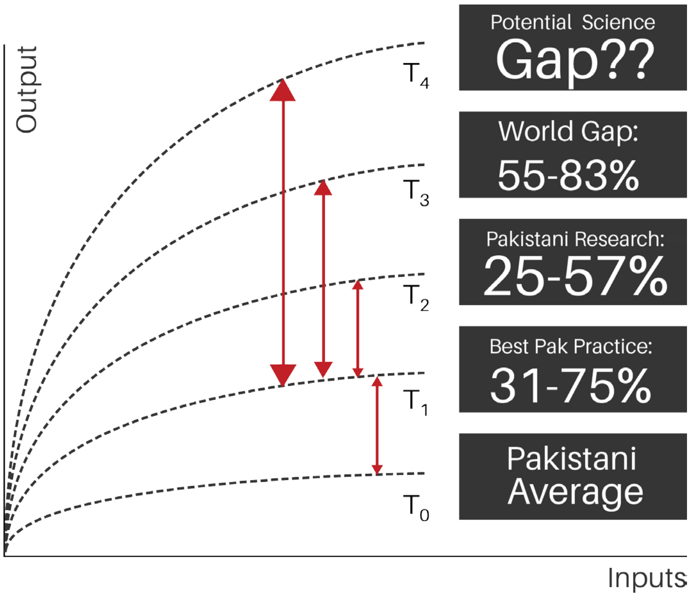

Figure: 2: Productivity Gaps for Pakistan's Major Crops (**Credit: Dr. Shaukat Hameed Khan**)

that given a challenging target and appropriate resources they can deliver against all odds. More often than not, the challenge has been to find a consistent vision, direction, and policy for science (governance) and channel this into benefit for the society (implementation).

Take the case of agricultural yields, for instance. A 2005 Expert Committee Report on Agriculture puts the national average yield for wheat at 2325 kg/ha while the average yield with progressive farming was put at 4625 kg/ha and the research potential yield at 6808 kg/ha.[3] Similar improvements in yields can be achieved for other crops as well. This clearly demonstrates that while science may provide an almost tripling of yield in wheat, lapses in implementation form significant bottlenecks for the realisation of this potential. These lapses are often of a relatively mundane nature – such as inability to provide quality seeds, timely water, farm inputs and implements, pricing and storage policies, and education and extension to farmers – that could significantly benefit from a better governance and implementation regime. Figure 2 highlights the gaps as well as the opportunities. Only after the implementation gaps (T_1-T_0 and T_2-T_1) are addressed the scientific potential (T_3-T_2 and T_4-T_3) be realised through better application of science and technology.[4]

While policy consistency and governance have often been found lacking, individual brilliance and raw talent has been in ample abundance in Pakistan. It is this determination – to win against all odds – and sheer brilliance and talent of its people that has defined the Pakistani nation since its birth in 1947. Pakistani scientists and technologists have often performed exceptionally well in more supportive environments abroad and, when given an opportunity, have achieved significant – though isolated – successes at home. It is precisely this talent that puts Pakistan apart as one of the very few Muslim countries – if not the leader of the pack - to have demonstrated an uncanny ability to achieve the impossible in science and engineering. What is needed, though, is a method and a degree of consistency through which the STI infrastructure can effectively and consistently deliver major societal benefits.

In many other ways, the story of STI in Pakistan is a typical developing country saga: too many immediate challenges, competing demands on the limited resources, and difficulty in appreciating the need to take a long term perspective, especially the need for investments in STI for socioeconomic development. The external factors identified in Figure 1 above – such as an unfavourable security environment – have especially played a key role in limiting what Pakistan could achieve in STI. But whenever a clear priority has been established, Pakistan's STI system has delivered notable successes, especially the Green Revolution of the late 1960s and 1970s; the major thrust to set up core heavy industries and related infrastructure in early 1970s; the nuclear power and nuclear weapons programme during the 1980s; and missile development programme of the 1990s.

The main challenge has been leveraging of these successes to develop a consistent national priority and focus on STI as a force for socio economic development. The disruptions caused by regime changes and policy reversals, undue influence of external players, and decreasing fiscal space because of the country's security challenges has hampered progress and proper institutionalisation of the STI system. As a consequence the virtuous cycle of investment in public science and harvesting of private profits has not yet taken off, and hence the benefits provided by the scientific community to Pakistani society are not fully understood and appreciated.

A greater and more open dialogue on core issues of national governance and resource allocation in the public sphere will hopefully create a more consistent national agenda for socio-economic development with STI at its core. The challenge is to appreciate the immediate challenges that the nation faces while keeping the focus on the long term.

These and many more important themes form the various chapters of this report.

The following is a summary of each of the chapters in this study.

Chapter 1 is a mapping exercise. This chapter provides a brief historical overview of STI policymaking and policy infrastructure in Pakistan. It then outlines the main inputs and outputs in Pakistan's STI system within a broader economic, historical and political context.

Chapter 2 looks at the people behind Pakistani STI. Here the challenge facing Pakistan's policy-makers is how to cultivate Pakistan's most precious asset- it's talented and hardworking people - into a skilled STI workforce. This chapter begins by exploring Pakistan's educational system and identifies other human capital priorities that should not be overlooked.

Chapter 3 looks at the range of scientific capacity across Pakistan through an analysis of the places where STI activities takes place. This chapter surveys the spread of STI capacity across Pakistan's historical and geographical landscape, highlighting places where exciting research is occurring and promising centres of innovation are emerging.

Chapter 4 considers business innovation in Pakistan. It discusses the size and scale of private sector innovation, entrepreneurship and R&D in Pakistan, as well as major barriers to innovation and how they might be remedied.

Chapter 5 looks at the contribution of Pakistani culture to supporting its STI ambitions. It looks at how religion, history, gender and public attitudes affect the place of science in wider Pakistani society.

Chapter 6 discusses the sustainability issues and vulnerability to Pakistani society due to its fragile natural environment. In recent years, Pakistan's socio-economic and political foundations have been badly challenged by a massive earthquake, major floods, droughts and a crippling energy crisis. Yet this also creates a major opportunity for Pakistani science.

Chapter 7 identifies opportunities for and barriers to collaboration between Pakistan and the wider international scientific community. It reviews patterns of Pakistan's collaborations globally and with OIC member countries. This chapter also looks at different policies, programmes, and initiatives that could strengthen these activities.

Chapter 8 summarises the major strengths and weaknesses of Pakistani STI, and provides a prognosis for future success and constructive ways forward. This takes the form of a set of recommendations that together address how STI could become a greater priority at the highest levels of policymaking and gain grassroots support in broader society.

In order to integrate these various themes into a holistic view of a science and innovation system, an integrated case study of the agricultural sector is used across chapters. These caselets have used the public policy framework (figure-1) to integrate and substantiate key learnings from each chapter and apply these to a sector of great importance to Pakistan.

Throughout the report, the authors have sought to be as comprehensive as possible – given the space constraints – while acknowledging the fact that it is almost impossible to do so keeping in view the immense breadth of the scope, the tremendous diversity of Pakistan and its rich and often complex history, and the demands of doing justice to the narrative style of this report. This report is not designed as an exhaustive review of Pakistan's STI landscape or policy but only meant to create a dialogue and debate within the society. Also, treatment of innovation in defence and strategic sectors as well medicine, health, and social innovation is, at best, partial for lack of better access or prioritisation.

Any errors – of commission or omission – in not appropriately recognising or giving credit where it was legitimately due are purely unintentional.

Pakistan Innovation Review

This report was originally commissioned as a part of a series of case studies on countries of the Islamic World as a part of larger multinational research project. Inspired by signs of renewed ambition and investment, the project sought to map the changing STI landscape across a diverse selection of countries with large Muslim populations in the Middle East, Africa and Asia.

Reflecting the collaborative nature of the project, this report is jointly authored by Dr Athar Osama, Dr Syed Zahoor Hassan and Dr Kamran Ali Chatha. Dr Osama is a science policy analyst, consultant, and advisor and the Founder and Chief Executive of Pakistan Innovation Foundation, the Founding Partner of Technomics International Ltd., and Founder and Editor of The Muslim World Science Initiative and Muslim-Science.Com. Dr Syed Zahoor Hassan and Dr Kamran Ali Chattha are the Professor and former Vice Chancellor, and Associate Professor at Lahore University of Management Sciences, respectively.

Over several months of fieldwork between November 2009 and September 2010 the authors consulted over 250 policymakers, entrepreneurs, scientists and economists across seven Pakistani cities: Karachi, Islamabad, Lahore, Faisalabad, Rawalpindi, Sialkot, Taxila and Kamra.

The study was kicked off with a Launch Event on May 27, 2010 at LUMS followed by a series of workshops and focus groups across a number of key industry sectors. The report was completed in March 2011 and submitted for peer review thereafter. A series of unfortunate circumstances over the next year delayed the publishing of the report and later resulted in Pakistan's withdrawal from the project altogether. This report is now being published by its team of authors through Pakistan Innovation Foundation for debate and posterity. We believe this somewhat critical review of Pakistan's STI policy and performance will generate an important debate and dialogue within the society that is urgently needed for Pakistan to move forward and progress.

The research team is grateful to Dr Iftikhar Ahmed, former Director General of the National Agricultural Research Council for hosting the Focus Group on Agriculture, Food, and Animal Sciences at Islamabad, and Lt. Gen. (Retd) Abid Ghumman, former Secretary of the Ministry of Defence Production, for hosting the focus group on Defence and Strategic Industries at Rawalpindi.

A number of institutions and individuals went out of their way in working with and hosting members of the research team and contributing helpful ideas. In particular, we want to thank Dr Ansar Pervaiz (former Chairman, Pakistan Atomic Energy Commission); Dr Iqrar A. Khan (Vice Chancellor, Agriculture University, Faisalabad); Dr Arshad Ali (former Principal, School of Electrical Engineering and Computer Sciences at NUST); Mr.Shahid Zaki and Izhar Mirza Husain (former Directors of EMBA and Executive Education at Institute of Business Administration, Karachi, respectively); Mr Zia Imran (former Managing Director, Pakistan Software Export Board) and Ms Jehan Ara (President, Pakistan Software Houses Association); and Mr Asad Umar (Former CEO, Engro – Pakistan) for their support.

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Pakistan's Higher Education Commission provided support to the research team.

A number of individuals played a critical role in facilitating the research team and making the study possible. Ehsan Masood accompanied the lead researcher on the initial scoping trip to Pakistan. Also noteworthy is the support and guidance of Dr Atta ur Rahman (former Co-ordinator General, COMSTECH), Dr Kausar Abdulla Malik (former Chairman of Pakistan Agriculture Research Council and Professor, Forman Christian College and University), Dr Anwar Nasim (President, Pakistan Academy of Sciences). Thanks to Mr Shamsh Kassim-Lakha (former Vice Chancellor of The Aga Khan University), Mr Zia Imran (former Managing Director of Pakistan Software Export Board, and Dr Adil Najam (former Vice Chancellor, LUMS and Dean Frederick S. Pardee School of Global Studies at the Boston University) for comments on early drafts of the report.

The authors were assisted by a number of research assistants, namely Aziz Omer, Usman Latif Butt, Umair Ahmed from LUMS; and Rasha Rahman, Faizan Usmani, and Nadeem Jahangir from Technomics International Ltd who accompanied us on interviews, sat in on focus groups, and drafted case studies.

The authors are grateful to anonymous peer reviewers and a number of institutional partners who provided helpful advice and guidance. Any mistakes or shortcomings are the responsibility of the authors.

1. Mapping

The story of STI in Pakistan begins with Dr. Salimuzzaman Siddiqui, FRS – an outstanding natural product chemist who isolated and characterised many chemical compounds from plants of medical importance. Starting out at the Indian Council for Scientific and Industrial Research, he migrated in 1951 to Pakistan on the request of the country's first Prime Minister, Mr. Liaquat Ali Khan, to become his Science Adviser.[5] Salimuzzaman Siddiqui quickly became Pakistan's pre-eminent scientist and the country's greatest advocate of science for almost two decades before Dr. Abdus Salam, FRS (1926-1996), the country's first and only Nobel Laureate, would eclipse his influence in the early 1970s. Salam – a leading theoretical physicist whose work on the unification of the weak and electromagnetic forces that won him the Nobel Prize (1979) was the chief science advisor to the President from 1961-1974. He played a major role in encouraging the creation of scientific infrastructure including the setting up of Space and Upper Atmospheric Research Commission (SUPARCO) and the Pakistan Atomic Energy Commission (PAEC) and promoting the peaceful use of atomic energy. As founder and Director of the International Centre for Theoretical Physics in Trieste he ensured generations of scientists could benefit from high-level research training while being able to contribute to science in their own countries. Abdus Salam would continue to have a towering influence on Pakistan (see textbox 1-1).

Siddiqui set up the Post Graduate Institute of Chemistry at Karachi University in 1967, later renamed the Hussain Ebrahim Jamal (HEJ) Research Institute of Chemistry (see textbox 1-2). In the early 1970s, he took on a young and ambitious scientist as his protégé and successor.[6] Fresh out of post graduate work at Cambridge University and Kings College, a young Atta ur Rahman would have shown the necessary signs of someone willing, and able, to take over the reigns of Siddiqui's institute and, later, his mantle as Pakistan's leading champion of S&T.[7]

This chapter provides a brief historical overview of STI policymaking and policy infrastructure in Pakistan. It then discusses the main inputs and outputs in Pakistan's STI system within a broader economic, historical and political context.

Salimuzzaman Siddiqui

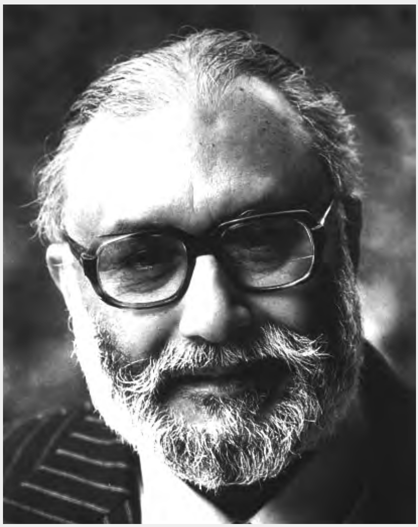
HI, MBE, SI, DPhil, FPAS, FRS, was a Pakistani organic chemist, versatile scholar, and a leading scientist in the natural product chemistry.

Born: October 19, 1897

Mohammad Abdus Salam

A Pakistani theoretical physicist who, upon sharing the 1979 Nobel Prize in Physics for his contribution to electroweak unification

Born: 29 January 1926



Atta ur Rahman

A Pakistani organic chemist and a leading scientist in the field of natural product chemistry, with approximately 983 important publications in the field of Organic chemistry, including his works referenced in 155 books largely published by publishers in Europe and the United States.

Born: 22 September 1942

Mumtaz Ali Kazi

A Pakistani chemist who was the Science Advisor to President Zia Ul Haq. MA Kazi played a formtive role in the creation of Comstech and the Islamic Academy of Sciences

1928-1999

Textbox 1-1: Abdus Salam School of Mathematics Sciences (ASSMS)

Government College University (GCU) in Lahore has a rich history spanning over a century and prides itself as the alma mater of the country's first and only Nobel Laureate, Dr Abdus Salam. GCU enjoyed its golden period of mathematics in the 1930s and 1940s with the eminent mathematician Professor Serva Daman Chowla, who wrote more than 350 papers, making significant contributions to number theory and combinatorics. The Abdus Salam School of Mathematics Sciences was established at GCU in 2003. Through the help from Higher Education Commission's Foreign Faculty Hiring Programme, Dr AD Raza Choudary, the Schools' first director, was able to attract researchers from Eastern Europe and the former Soviet Republics. As these "star scientists" arrived[8], so did their students and a critical mass of scholars emerged. Slowly but surely, the School's much sought-after mathematicians are beginning to fill the gap that previously existed in Pakistan for many years. The School's faculty currently include eight professors with expertise in areas such as topology, algebraic geometry, number theory, and theoretical physics. The School began by offering fully funded[9] scholarships to MPhil and PhD fellows to attract talented scholars. A number of the School's students have published in ISI indexed journals and faculty maintains an active interest in publishing[10].

Textbox 1-2: HEJ Research Institute of Chemistry

Established in 1967, the Post Graduate Institute of Chemistry at Karachi University has flourished as one of Pakistan's most prolific research institutes. A research grant from Germany, secured through the support of Professor W Voelter of Tuebingen University, set things in motion and others from the US, and UK transformed the institute into the finest centres in Asia, and one of the best in the world, in the field of natural product chemistry.[11] In 1976, a gift from a Pakistani industrialist led to renaming of the Institute to Husein Ebrahim Jamal (HEJ) Institute of Chemistry. Dr Atta ur Rahman became co-Director in 1977 and Director in 1990 and embarked upon an ambitious effort to equip the lab and secure funding through multiple sources.[12] HEJ has carried out research into the classification and properties of a number of naturally occurring plants in Pakistan, including medicinal plants. It was the first institution in Pakistan where faculty promotions were performance-based and offered fully funded PhD fellowships to attract talent.[13] These have paid off. In 2010, HEJ published 220 papers in international journals.[14] HEJ regularly hosts foreign scholars and visitors at its campus in Karachi. HEJ has also set up an Industrial Analytical Centre to support local industry to carry out chemical analyses.

In 1994, HEJ became the first of the International Centres of Science and Technology established under the auspices of The Academy of Sciences for the Developing World (TWAS) and became part of the International Centre for Chemical and Biological Sciences (ICCBS). In 2004, HEJ received the prestigious Islamic Development Bank Science Prize for its contribution to national development in a member country. HEJ holds the singular honour of winning the award a second time in a different category in 2010.

Over the years, the Centre has grown considerably in its breadth with the creation of adjoining facilities and research centres such as one in Molecular Medicine and Drug Discovery as well as a planned research hospital facility to carry out bioequivalence testing and ultimately drug trials, etc.

1.1 A brief history of STI in Pakistan

At the time of partition, Pakistan was an under-developed area even relative to some other developing Asian countries. "The systems of production, transportation, trade and consumption yielded a very low standard of living...agricultural methods were for the most part primitive...[and] industry was nearly non-existent.[15] The upheaval of the transfer of over 6 million people across the borders of Pakistan and India – the world's most intense migration – necessitated that the new government's earliest priorities would be to provide food and shelter and rehabilitate the migrants[16] and begin the reconstruction of the country's nascent economy.

On the occasion of the issuance of new Pakistan Coins and Notes by the Finance Ministry on April 1st, 1948, Pakistan's founder Mohammed Ali Jinnah noted this sentiment:

> I have no doubt in my mind about the bright future that awaits Pakistan when its vast resources of men and material are fully mobilized. The road that we may have to travel may be somewhat uphill at present but with courage and determination we mean to achieve our objective, which is to build up and construct a strong and prosperous Pakistan.[17]

It was quite natural that it took a while before the leadership's attention could move from the most urgent and the basic to long-term and strategic. Even the first five year plan (1955-60) envisioned a public and private expenditure of Rs. 10.8 billion and focussed primarily on raising the national income by 15% over 5 years through a mix of export promotion and import substitution approaches.[18] Agricultural development was a major component of the action plan as was industrialisation started through the creation of Pakistan Industrial Development Corporation (PIDC) in 1952 with credit from IDA.[19] The main objective of PIDC was to act as a catalyst for industrialization and it played a pioneering role in setting up an industrial base in key sectors like chemicals, fertilizers, cement, light , heavy and precision engineering.

1.1.1 The early years (1947-1965)

Despite inheriting a paltry STI infrastructure at the time of Pakistan's creation in 1947, a number of important institutions were created during the first decade after independence. Dr Salimuzzaman Siddiqui was responsible for setting up the institutional foundations of science in his newly adopted country. This included the four research councils:

- Pakistan Council for Scientific and Industries Research (PCSIR);
- Food and Agriculture Council;
- Medical Research Council;

- Atomic Energy Research Council, later the Pakistan Atomic Energy Commission (PAEC);

Space and Upper Atmospheric Research Commission (SUPARCO) was created initially as a directorate of PAEC in 1962 and constituted later, in 1981, as a separate Commission.[20]

However, compared to other newly independent countries, especially India where the foundations of IITs were being laid, teaching of science and technology at the college level did not receive serious attention as effectively very little investments were made in science and engineering education at the college and university level.

During this period Pakistan joined western alliances against communism and started receiving military equipment and related assistance to bolster its armed forces. This skewed the country's national security priorities, increased dependence on foreign aid, and significantly diminished the room and capacity to evolve indigenous priorities and plans. This era has been described as 'foreign aid dependent regime' and observers have claimed that "once the aid stopped so did growth in the economy."[21]

A watershed event was the appointment of a Scientific Commission in 1960. It made 55 recommendations including the creation of a Pakistan Science Service along the lines of a Civil Superior Services. This would have firmly established the importance of the scientific profession on an equal par with the powerful administrative service and the allocation of at least 2.5% of the federal budget for science.[22]

From 23-27 August 1965, after being in power for nearly seven years, President Ayub Khan called a meeting of the country's leading scientists to discuss the current state and future development of STI in the country. In his inaugural speech, the President laid out his rationale for supporting science by pointing to a stark choice:

> "Either we go forward and acquire mastery over the widening horizons of scientific knowledge and thought for the betterment of our people, or we stay behind, as those who preferred the placidity of the old way of life to the excitement and adventure of the new order."

Just a week later on 6 September 1965, Pakistan was engaged in a full-scale war with neighbouring India. The country's era of relatively stable politics, strong growth and prosperity, and political support to become a scientific leader had proved short-lived.

1.1.2 The post war consensus (1966-1972)

As a consequence of the 1965 war and subsequent arms embargoes from the West, the burden of funding Pakistan's enhanced security needs fell squarely on a war ravaged economy further skewing the budgetary priorities and a consensus of sorts emerged on the importance of staving off the security threats to the country. By the end of Ayub's government in 1968, Pakistan's economy had begun to stagnate. In the second half of the 1960s, Pakistan was beset with a series of famines and food shortages which called into question the ability of the country to support its growing population.

A significant scientific feat of this era of political instability and uncertainty was the ushering of the Green Revolution in Pakistan, among other parts of the developing world. Significant advances in agricultural productivity were made through use of better seeds, mechanisation and chemical fertilisers (see section 3). The green revolution was instrumental in correcting the imbalance between population and agricultural production, ensuring food security for the country.

1.1.3 The strategic imperatives (1973-1988)

In 1972, amidst the trauma of the breakup of Pakistan, Zulfiqar Ali Bhutto led the united political opposition to power in the western half of Pakistan. Represented by his campaign slogan 'Roti, Kapra, aur Makan' (food, clothing, and shelter), Bhutto's mandate for change meant the new government's priorities were populist and focussed on a long term nationalistic development agenda. Investments were made in heavy engineering industries (steel, fertilizer and cement) besides projects to build another port and the Indus Highway to link the country from the north to south on the western side of the river Indus.[23]

During the 1960s, the Pakistan Industrial Development Corporation (PIDC) had executed upon its mandate of creating industries in the public sphere and then selling them off to private sector thus laying the foundations of capitalist industrial economy in Pakistan. These sales, often to a small number of industrial and financial groups, created a sense of gross inequalities within the country and the spectre of '22 families' owning vast proportion of the country's wealth became a preoccupation with the populace.[24] Delivering on an election promise, Bhutto nationalised industries and educational institutes. As part of the nationalisation movement in the following decade, private sector friendly policies were reversed, resulting in a loss of confidence in private sector investment in Pakistan. These actions have sometimes been blamed for having been instrumental in breaking the back of capitalism and entrepreneurship in the country for decades to follow (although a gradual process of phased denationalisation since the 1980s continues to this day).

With the exception of the nuclear weapons programme, other science institutions did not get adequate funding.[25] However, several new engineering universities and colleges were opened[26] and the compensation structure of college and university teachers was bought at par with that of the armed forces and civil bureaucracy. In line with the broader nationalistic policy agenda of self-reliance, a number of state-owned enterprises, such as the Heavy Mechanical Complex (HMC) and Pakistan Steel Mills (PSM) were created to develop the heavy engineering sector within the country (see textbox 1-3).

In January 1971, Prime Minister Bhutto had chaired a historic meeting of PAEC scientists and engineers, at which he appointed Dr Munir Ahmed Khan as the new PAEC Chairman and announced the plan to pursue a nuclear weapons programme.[27] India's decision to test its first nuclear test device on 18 May 1974 was the final straw that set the course of Pakistan's own nuclear programme to, in Bhutto's own words, 'it's natural conclusion'.[28] A new chapter had opened in Pakistan's STI policy with serious repercussions for the country in significant ways. The policy of building a portfolio of nuclear research continued under General Zia ul Haq's rule between 1977 and 1989. Pakistan developed a nuclear enrichment capability for military purposes and probably had developed the complete designs of an atomic weapon by the end of General Zia's rule.[29] This set in motion a new set of funding priorities for successive Pakistani governments.

With these successes came a new found confidence. Pakistan saw itself as a champion of science in the Islamic World through, among other mechanisms, the creation of the OIC Standing Committee on Scientific and Technological Cooperation (COMSTECH) in 1981 (see section 7.3.1).[30] A number of new institutions such as National Institute of Electronics (NIE) in 1979, National Institute of Oceanography (NIO) in 1981, and National Institute of Silicon Technology in 1981 were created, but these were not funded commensurate with the challenges faced in these areas. This era also saw Pakistan playing a key role in the war against USSR in Afghanistan with a massive military build up supported by the United States.

1.1.4 A decade of challenges (1989-1998)

The Soviet retreat from Afghanistan coincided with the democratic rule in Pakistan with its own challenges, namely, political instability and pressure on financial resources.

However, during the late 1980s and 1990s different research institutes were set up in emerging areas of science and technology, most notably, biotechnology and genetic engineering, molecular biology, desertification, water resources, hydrocarbons, and renewable energy, though funding limitations continued to prevail. In particular, considerable emphasis was placed on biotechnology and genetic engineering with the creation of NIBGE in Faisalabad.[32] Between the late 1980s and early 1990s, an S&T manpower development programme ran under the Ministry of Science and Technology (MoST) under which 1600 professionals were sent abroad to do PhDs at the cost of Rs 2700 million.[33]

STEDEC ("Scientific and Technological Development Corporation") was established with an initial capital of Rs. 20 million[34] to help commercialise public R&D. The country produced its first National Technology Policy and Technology Development Action Plan in 1994. An Engineering Development Board (EDB) was set up to promote the engineering industry in the country and played a constructive role in promoting greater localisation in the automotive sector.

However, throughout the following decade, research and development (R&D) funding declined from 0.27% of GDP in 1989 to 0.11% in 1999-00 (see figure 1-2). In spending terms, Pakistan was lagging far behind even the developing world during much of the late 1980s and 1990s. The average R&D spending in 1999 for the whole of the developing world was 0.9%. The figure for the developed world was at 2.3%.[35] Since Pakistan was building on a very low base, it lacked critical mass to make an impact in a variety of areas.

It is difficult to ascertain the precise allocation for S&T in the earlier Five Year Plans because these were made under other heads, such as agriculture, and water and power, etc. It was only in the seventh Five Year Plan (1988-93) that S&T became a separate head. Subsequent allocations were Rs 2.8 billion (1988-93) or 0.008% and Rs. 4.6 billion (1993-98) or 0.007% of the total Plan budget. Actual expenditure on S&T, through other budget heads, might have been higher. Although allocation of funds for S&T increased in absolute term from one Five Year Plan to the next, their utilization rate declined from 80% in the fifth Five Year Plan (1978-83) to 15% in the first three years of eighth Five Year Plan (1993-98)[36].

Textbox 1-3: The beginnings of a heavy engineering sector

Starting from humble beginnings in the 1950s, Pakistan focussed its attention on developing low technology industry, such as diesel engines, pumps, and textile machinery in the 1960s to capital engineering goods during the 1970s. In 1970s, heavy industries, such as fertilizer, cement, steel, and defence, flourished in the state sector as part of a detailed industrialisation strategy. Established with Chinese collaboration in 1971, the Heavy Mechanical Complex (HMC), along with the Pakistan Steel Mill and Pakistan Machine Tool Factory (PMTF) were major breakthroughs in establishing an indigenous engineering industry in the country. Today, HMC produces and exports sugar, cement, petrochemical, and power production plants and various types of construction equipment, apart from defence and related machinery. In 1973, National Engineering Services Pakistan Ltd (NESPAK) was also created as a private limited company by the Government of Pakistan that became the premier engineering consultancy provider within the country. By 2011, NESPAK had delivered over 3000 projects in over 35 countries amounting $170 billion[31].

Over the years, a number of private sector firms have also ventured into heavy engineering sector and some have begun to flex their muscles as international players. DESCON Engineering Services has become one the country's largest EPC services provider with major operations in the Middle East and Gulf and a workforce of over 40,000 employees from over 29 countries. The Al-Tuwairiqi Group of Saudi Arabia is in the process of establishing a private steel mill in Pakistan. It seeks to become a licensor of the innovative energy-efficient dry reduction of iron process, and also hopes to provide extensive design and fabrication services to other clients in Pakistan and the Middle East. Qadri Brothers, a Lahore based engineering company, recently exported one of the world's largest most state-of-the-art sugarcane crushing unit to the United States. Millat Tractors has the distinction of producing the world's cheapest tractors in Pakistan.

1.1.5 The revival of funding for scientific research (1999-2008)

With the 9/11 and Pakistan's decision to support US in fighting Al-Qaeda, funds in civilian and military aid again started flowing, thus giving an uplift to the ailing economy. Pakistan's STI landscape also underwent something of a revival in the first half decade of the 21st century during the military rule of General Pervez Musharraf. Under the watch of Professor Atta ur Rahman, FRS as Minister for Science and Technology from 1999 to 2001, the budget of the Ministry of Science and Technology (MoST) increased by over 60-fold.[37] A number of programmes to enhance manpower development, repair and replenish laboratory equipment, and incentivise scientists were undertaken. This helped to address important funding imbalances in the system. Universities began, for the first time in Pakistan's history, to receive the kind of resources necessary to maintain a credible capacity to do research.

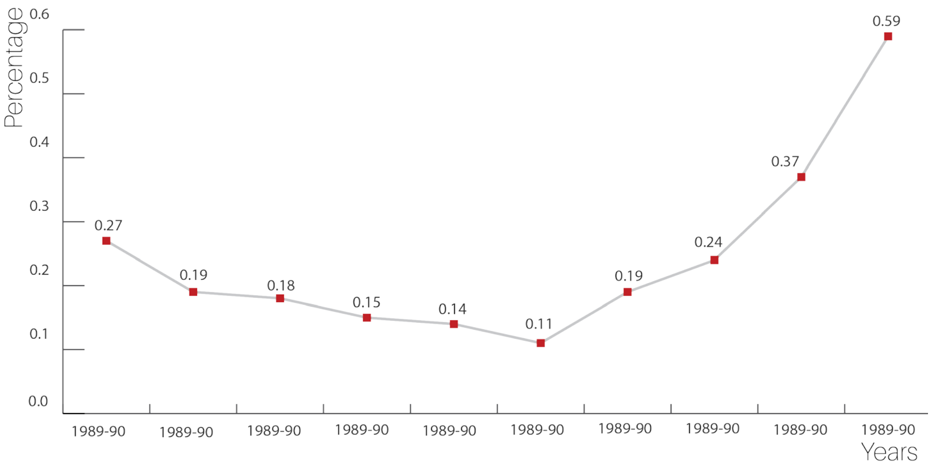


Figure 1-2: R&D Expenditure as percentage of GDP (Source: PCST, 2009)

In 2002-3, Pakistan found itself engaged in global debate about the importance of higher education in twenty first century knowledge economies. A Task Force on Higher Education recommended replacing the University Grants Commission and creating a much empowered Higher Education Commission (HEC). In 2003, Atta ur Rahman was appointed as HEC's first Chairman. Under his chairmanship, funding for the country's universities increased more than 10 fold from Rs 3 billion in 2002 to over Rs 30 billion in 2007.[38] This also put into motion a wide-ranging reform agenda comprising a large number of different programmes aimed at building human capital, infrastructure, research capacity, and curriculum, etc. as well as a substantial increase in number of new universities created.

1.1.6 The new challenges (2008–)

Energy prices skyrocketed in the 2007-8 timeframe causing economic hardship and budgetary imbalances. Musharraf's military-backed government lost the 2008 General Elections. The new Pakistan People's Party government – under pressure on both domestic and foreign fronts – made a marginal nominal increase in S&T funding. Embroiled in a political controversy, HEC's funding was cut by as much as 40%.[39] MOST's budget was further cut by half. S&T funding across several ministries were reduced from Rs 50.5 billion (US $590 million) in 2009 to Rs 32.3 billion (US $377 million) in 2010.[40] Even deeper cuts were avoided for the fear of student agitation and en masse resignation of a large number of university Vice Chancellors.[41] Both the Science and Technology Minister and HEC Chairman publicly complained about these budgetary cuts, and called for a greater appreciation of the contribution of S&T to Pakistan's national development.[42] These cuts posed serious challenges to the sustainability of science and innovation.[43]

1.2 Key factors in Pakistan's STI system

There are three critical and equally important elements to Pakistan's public sector S&T infrastructure (see figure 2):

- University based S&T;
- public sector S&T;
- strategic and defence S&T.

Over the years, these three different elements of the national STI ecosystem have achieved varying levels of political patronage and societal recognition, leading to different rates of growth and levels of performance. This has also led to the duplication and turf wars between different bodies in this system. A relatively ill-developed private-sector R&D infrastructure can be added as a fourth element to complete the national S&T infrastructure. This is discussed in more detail in chapter 4.

1.2.1 University based S&T

1.2.1.1 Higher Education Commission

Created in 2002, HEC is responsible for regulating and distributing federal funding to institutions of higher learning (such as, universities and degree granting institutions).[44] HEC began with an ambitious reforms agenda to develop university faculties; enhance the quality and quantity of research; and improve access to tertiary education. To achieve these objectives, HEC has established a large number of programmes and initiatives under three major categories: human resources; research and physical infrastructure; and curriculum, governance and learning innovation.[45]

1.2.2 Public sector S&T

1.2.2.1 National Commission of Science and Technology

Established in 1984, the National Commission of Science and Technology (NCST) sits at the apex of S&T policymaking in the country. NCST is designed to coordinate inter-ministerial and inter-provincial S&T programmes; link S&T efforts with production and development plans; and establish linkages with international organisations.[46]

The Pakistan Council for Science and Technology (PCST) is the Secretariat of NCST. It is responsible for advising the Government on S&T policies and suggesting measures to promote the development and application of S&T in the country. PCST convenes expert committees to provide advice on scientific issues as and when required. In collaboration with MoST, PCST is responsible for developing plans that are put in front of an Executive Committee before they are approved by NCST.[47]

1.2.2.2 Ministry of Science and Technology

MoST is responsible for planning, coordinating and directing efforts to initiate and launch S&T programs and projects aimed at Pakistan's economic development.[48] One of MoST's principal aims is to build Pakistan's S&T capacity in the 21st century by moving into new markets; developing a larger pool of human resource to reverse the country's brain drain; creating the soft infrastructure needed to support STI; ensuring effective S&T governance; and enhancing the capacity of indigenous innovation systems.[49]

1.2.2.3 Planning Commission

The Planning Commission is the country's chief planning and development body responsible for long range development planning. It is the de-facto think tank of the Pakistani Government. Like NCST, it is chaired by the Prime Minister and headed by a Deputy Chairman, who holds the status of a Federal Minister. The Planning Commission produces Five Year Plans, 15 year perspective plans and national visions; as well as setting up task forces on important national issues. Over the years, Planning Commission has carried out a number of national vision exercises, most notable and recent being Pakistan 2025, 2030, and 2010 Vision exercises[50] – each involving significant components of science and technology.

Perhaps as important as its role as a think tank, the Planning Commission acts as the focal point for the collection and approval of all development projects submitted and approved as a part of Public Sector Development Programmes (PSDPs) and Annual Development Plans (ADPs) of the country.[51] S&T planning is coordinated and collated through the Planning Commission where a Section headed by a Member (Science and Technology) is dedicated to bringing this effort together into the national planning exercises.

1.2.3 Strategic and defence S&T

1.2.3.1 Strategic Plans Division

The Strategic Plans Division (SPD) along with the Ministry of Defence Production (MoDP) is responsible for the conventional defence and strategic (nuclear weapons and their delivery systems) industries and related scientific and research capabilities. A number of important labs within PAEC and defence laboratories fall under SPD's administrative control. The defence manufacturing and research capability falls under the control of the MoDP.

1.2.4 Important non-Public S&T actors

In addition to the above three tiers of public sector S&T infrastructure, other important non-public actors also feature in Pakistan's STI system.

1.2.4.1 Pakistan Academy of Sciences

The Pakistan Academy of Sciences is a non-governmental and non-political body of distinguished scientists. Established in 1951, it holds consultative and advisory status with the Pakistani government regarding problems about the development of scientific efforts in the country. At present there are 87 Fellows, 22 Foreign Fellows, and 8 members.[52]

1.2.4.2 Pakistan Science Foundation

The Pakistan Science Foundation (PSF) is an autonomous organisation under the Federal Ministry of Science and Technology (MoST) and is the apex body responsible for the funding and promotion of science and technology. PSF has two subsidiary organizations i.e. Pakistan Museum of Natural History (PMNH) and Pakistan Scientific and Technological Information Center (PASTIC).[53]

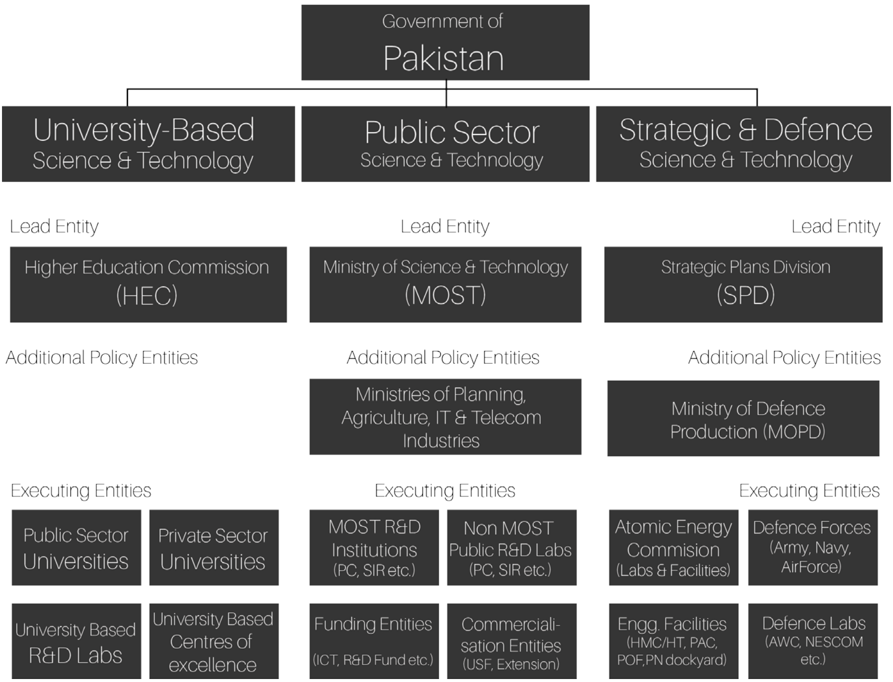


Figure 1-3: Pakistan's three tiered S&T infrastructure

1.3 A complex STI policy infrastructure

In Pakistan, the progress in Science and technology has largely depended on the influence and stature of particular personalities rather than a set of strong institutions championing its cause. S&T has flourished in periods when it was championed by strong personalities at the helm and floundered when they left (see section 1.1). Strong institutions, such as PAEC or the defence science establishment, are an exception rather than a rule. In fact, it is the confluence of both strong institutions and individual champions that is critical to the development of S&T. Two particular institutions are designed to play a formative role in the creation of STI policy.

The Planning Commission is responsible for putting in place both long-range (15-20 years) and short-term (annual and five year) development plans for the country. Over the years, the Planning Commission has produced a number of long-range perspective plans and visions. The Pakistan 2010 Programme launched in 1997 sought to create a "knowledge-led, just, tolerant and prosperous Pakistan."[54] However, implementation lagged behind the aspirations and the programme was shelved after a change in government in 1999. In 2007, the Planning Commission launched the Vision 2030 with an aim to create "a developed, industrialized, just and prosperous Pakistan."[55] The Vision 2030 programme provides a reasonable preamble for an STI policy document which gives appropriate emphasis, on competition, education and skills, knowledge, and STI.[56] However, as with other plans, follow up has been less than ideal. It is unfortunate that the recommendations of Vision 2030 – or even the mention of it – have not found any explicit expression in subsequent policy documents and implementation such a new STI policy approved by the Cabinet.

During the tenure of the previous government, a New Economic Framework (NEF) was launched that sought to correct the fundamentals of the country's economic structure with emphasis on often overlooked factors such as competition, urbanisation, and productivity improvements, etc. The NEF document also talked about S&T as one of the vehicles to correct some of these fundamentals but, as before, implementation remained a pipedream. The current government, on August 11, 2014, launched the Vision 2025 programmes as the latest attempt to provide a broad direction to the country's economic and social development. The government has claimed broad-based support for its vision and have alluded to a comprehensive mechanism to ensure implementation and performance oversight. However, whether this latest vision is any different in terms of implementability remains to be seen.

Given its record so far, National Commission on Science and Technology (NCST) has not been very effective in providing consistent S&T leadership at the national level. Although mandated to meet twice a year, NCST has only met three times (in 1989, 2000, and 2001) since its creation over two decades ago.[57] In a recent attempt to call the fourth meeting of this body, requests were made to relevant national ministries and bodies to submit proposals for the consideration of the NCST but PCST received only 'limited agenda proposals', suggesting a rather diminished status within the broader national policymaking infrastructure.[58] None of the projects approved at the previous two meetings were routed through the NCST Secretariat, as originally envisioned. In view of this, there have been calls to rethink the status and mission of NCST.[59] The recent document of National Science, Technology, and Innovation Policy – 2011 has even called for scrapping of NCST and the creation of a Cabinet Committee. Unlike other countries where S&T has achieved a status central to their development plans, MoST remains a largely peripheral Ministry unable to effectively drive Pakistan's S&T agenda.

It is not sufficient that S&T is a priority at the heart of government. The infrastructure to formulate and implement policy needs to work seamlessly to deliver quality science and beneficial innovation by drawing on the individual contributions of all the key elements of the STI system. Problems of duplication and lack of coordination between bodies responsible for implementation – a problem not quite unique to Pakistan or even developed countries in the West – mean that quality of desired outcomes often vary considerably.

Pakistan's agriculture and livestock STI system may provide the best illustration for the duplication and lack of coordination between a plethora of institutions that have spawned over the decades (see Text Box 4). Similarly, there is very little coordination and cooperation among the three main segments of the science and technology infrastructure. Unlike developed countries, the defense research establishment hardly funds any research at the universities nor does it seriously consider the commercial applications for defense-funded research or, with a few minor exceptions, private sector involvement in manufacture of defense equipment. These factors have hindered the accrual of important economic benefits from the investments in defense STI and hampered the long term sustainability of this STI investment model.

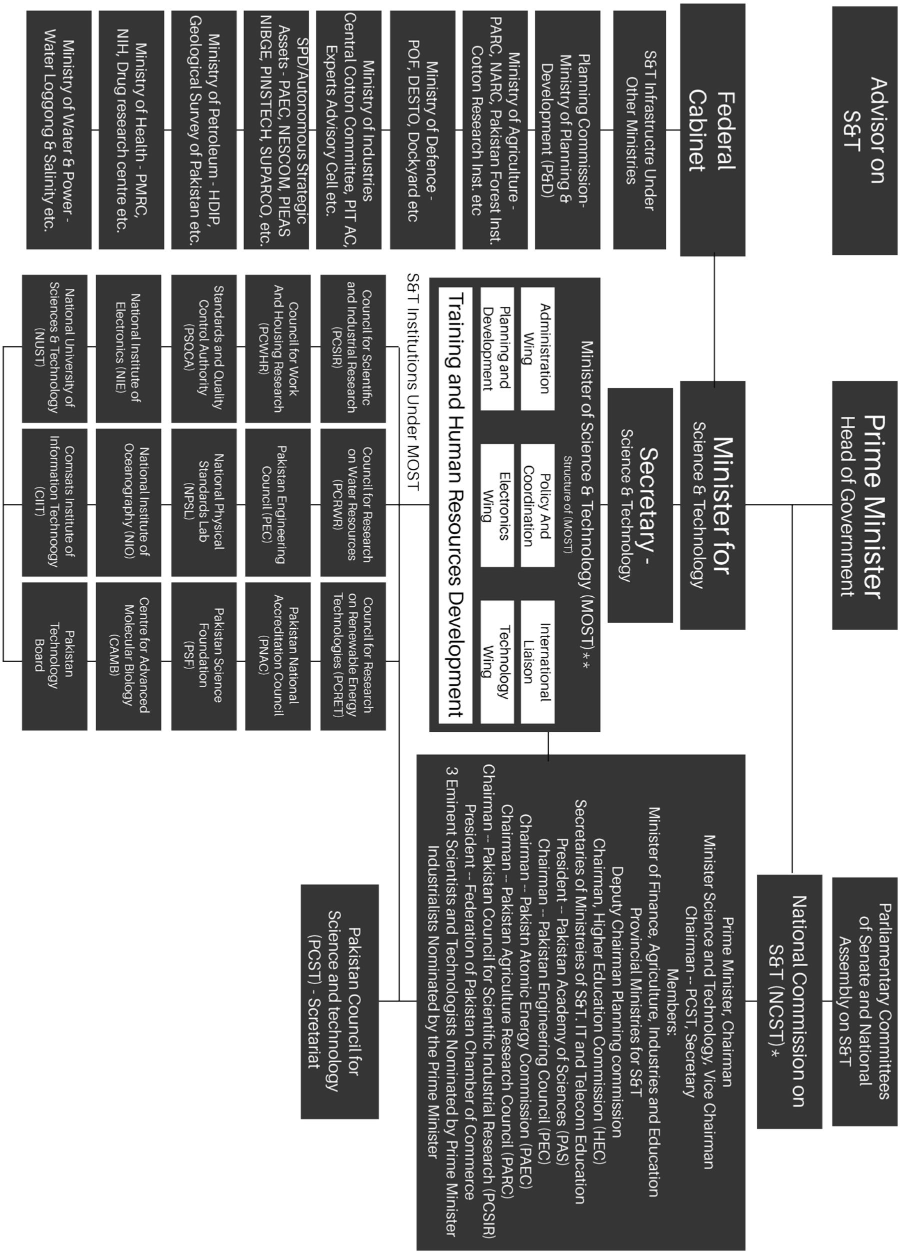


Figure 1-4: The structure of science policy advice and implementation in Pakistan

1.4 Inputs to the STI System

1.4.1 Human capital

In 2009, Pakistan had 162 researchers per million of its population. This compared slightly better than India (140) but considerably less than Argentina (895), Turkey (562), China (926) and paled against some of the developed countries, such as South Korea (4162) and USA (4651).[60]

According to a PCST survey in 2009, approximately 130,000 individuals worked in S&T.[61] Of this, more than 53,000 were researchers, 13,000 were technicians, and 64,000 were support staff. Of the 53,000 researchers, about 14% (7,296) worked in agriculture; 16% (8,648) in medicine; 18% (9,937) in engineering; 24% (12,930) in natural sciences; 14% (7,507) in social sciences; and 10% (5,257) in humanities. Of the 53,000 researchers active in public sector S&T organisations and Higher Education Institutions (HEIs) in 2008-9, only 5,205 (or less than 10%) had a PhD (see table 1-1).

	1947-2002 [55 years]	2003-2009 [7 years]
Discipline	**Number of PhDs**	**Number of PhDs**
Agriculture & Veterinary Sciences	363	450
Biological & Medical Sciences	589	601
Engineering & Technology	14	131
Business Education	11	58
Physical Sciences	688	677
Social Sciences	899	739
Arts & Humanities	683	377
Honorary	54	4
Total	3,821	3,037

Table 1-1: The growth in the number of PhDs in Pakistan (Source: HEC)

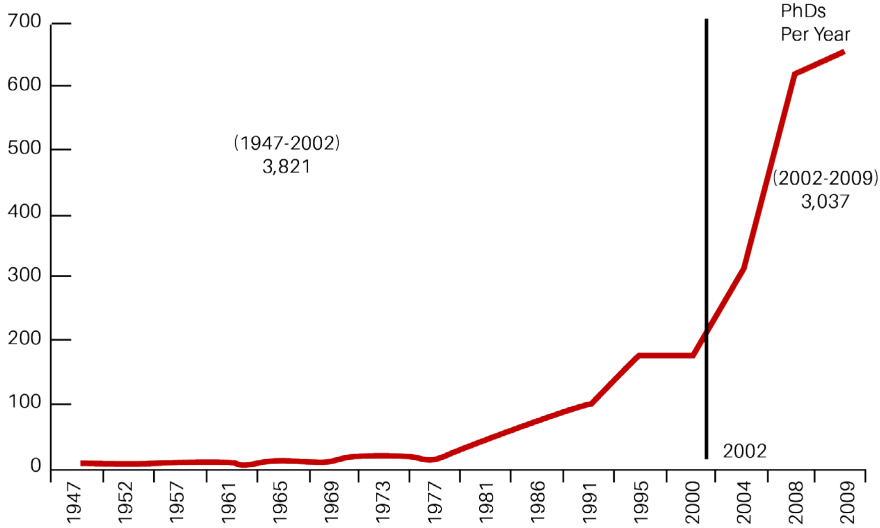


Figure 1-5: Exponential growth in the production of PhDs (Source: HEC)

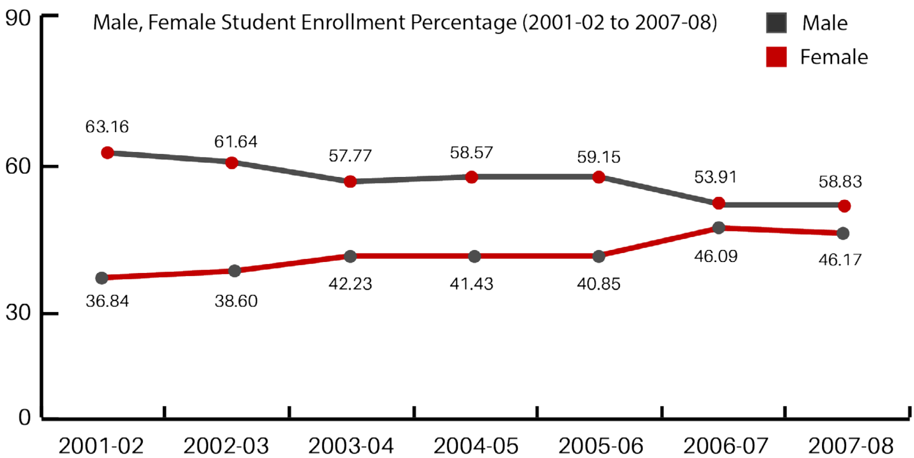


Figure 1-6: The gender balance in tertiary education (Source: HEC)

In recent years, there has been a considerable closing of the gender gap within the research professions. According to 2009 statistics, the male-to-female ratio of university enrolment was approximately 54:46 while about 35% of current PhD students were women (see figure 1-6).

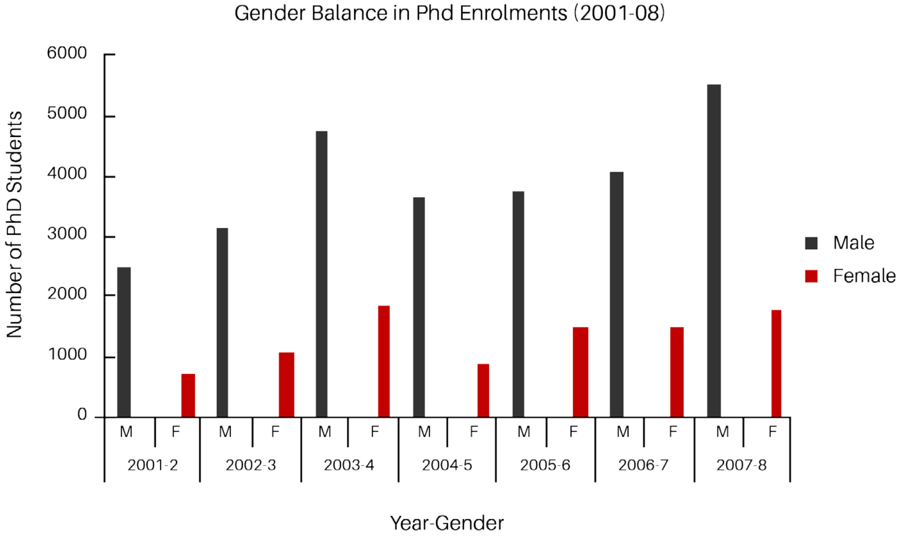


Figure 1-7: Gender balance in PhD enrollment n Pakistan

In recent years, HEC has initiated a number of research support programmes to create a positive enabling environment for research. A formal programme to fund research at the universities through a peer reviewed process was created. Several research collaboration programmes have been established and (co-)funded by HEC to provide opportunities for faculty to engage with researchers abroad.

Other key enabling interventions include[62] a digital library that provides access to cutting edge research and publications; an academic internet that links universities across the country with those abroad; an equipment sharing programme that allows universities to share costly equipment; and investment in laboratories and facilities.

1.4.1.1 Foreign Faculty Programme

HEC has initiated a number of programmes to ramp up the capacity to produce PhDs and fill the gaps while more long term measures bear fruit. One such programme is the Foreign Faculty Hiring Programme.[63] Although it is difficult to assess its overall impact, and a scientifically rigorous analysis has not yet been conducted by HEC,[64] there is anecdotal evidence of some success. For example, it has helped the Abdus Salam School of Mathematics to enhance country's standing in mathematics (see textbox 2-1). It also allowed Dr Shafaat Bazaz at Ghulam Ishaq Khan Institute (GIKI) to achieve his dream of positioning Pakistan as an important player in niche areas of emerging high technology (see textbox 2-4).

Textbox 1-4 Materials science and nanotechnology at Ghulam Ishaq Khan Institute (GIKI)

With a PhD in robotics and controls from France and having held positions at the Denmark Technical University and CMC Microsystems in Canada and USA, HEC's Foreign Faculty Hiring Programme allowed Dr Bazaz to move back to Pakistan as the Dean of GIKI's Faculty of Computer Systems Engineering in 2006. He soon realised that the ecosystem for creating complex Microelectronic Mechanical Systems (MEMS), including research staff, critical laboratory manpower and equipment, and know-how, was missing in Pakistan. He spent the next few years developing the soft and hard infrastructure needed to create MEMS devices in Pakistan. With the help of several funding entities, such as HEC and the ICT R&D Fund, and paying clients within the defence and strategic industries cluster in northern Punjab, Bazaz has been able to develop a number of MEMS devices, such as a thermally activated non-resonant micro-gyroscope (in collaboration with the Pakistan Institute of Engineering and Applied Sciences and Queens University, Canada) used in small-sized precision navigation devices such for aeronautics and space applications; a micro-accelerometer used in portable electronic devices and videogames for detecting motion; and an electro-statically actuated micro-gripper used to manipulate particles and materials at the nano-scale level.[65] The capability developed at GIKI and elsewhere could allow Pakistan to exploit these niche markets.

1.4.2 Funding for science and technology

Support for S&T and its smaller subset R&D, has varied over time and across sectors. According to PCST, the total S&T expenditure in 2007-08 was Rs 109.69 billion.[66] Of this, public funding has increased from Rs. 8.8 billion in 1999-00 to 73.7 billion in 2007-8. Over the last decade, as Gross Expenditure on R&D (GERD) has increased in absolute and per capita terms, the proportion of R&D performed within Higher Education Institutions (HEIs) has increased from a low of about 18% in 2002 to a high of 32% in 2005.

The fundamental shift in the funding pattern has been in the increase in development funding that allows institutions the financial room to invest in research infrastructure and projects. Non-development funds, although important, have grown at a considerably lower rate (see figure 1-8).

Nowhere has this been more obvious in the recent years than HEC funding where the majority of this recent increase in S&T funding has been directed. Over the years, the share of development funding within the higher education budget has increased dramatically, growing from Rs 420 million ($6.5 million) in 2001-02 to Rs 18 billion ($279 million) in 2007-8. The recurring (non-development) budget has grown from approximately Rs 3 billion ($45 million) in 2001-2002 to almost Rs 15.77 billion ($243 million) in 2007-08[67]. Even so, higher education spending as a percentage of overall spending on education remains lower (10-12%) than international best practice (30%).[68]

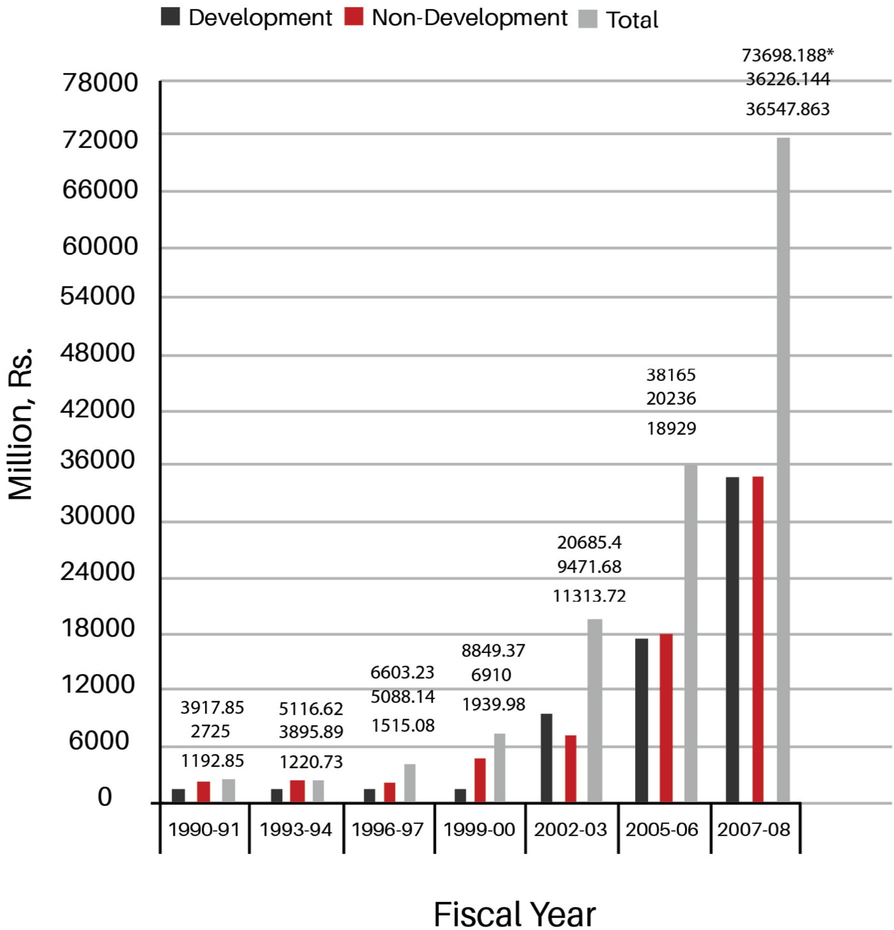


Figure 1-8: Government S&T Spending Over Time[69] (Source: PCST, 2009)

Some of these positive changes have since been reversed under budgetary pressures. For example, the actual development expenditure for Ministry of Science and Technology (MoST) was PKR 158 million in 1999-2000. It increased to PKR 2.41 billion in 2001-2002 before declining to PKR 609.889 million in 2010-2011.[70]

1.4.2.1 Sources and uses of funding

Of the Rs 109 billion of S&T funding in 2007-8, 67% was public and the rest was generated through a number of different sources. Rs 12.36 billion (or only 11.25%) were 'self-generated' funds and less than 5% were through international grants. For R&D, where PCST calculated Rs. 58.5 billion of total expenditure, the numbers were even more skewed towards public sector spending with 83% being spent by government sources, 10% by HEIs, 3% by business, and 2% by private and non-profit sources combined (see table 1-2).[71] This exposes an important vulnerability in the funding of R&D within the country, namely, a lack of private funding within S&T, in general, and R&D, in particular.

Source	S&T/R&D Organisations Expenditure	Higher Education Institutions Expenditure	Total Expenditure
Government Grant (Development)	25630.286	10917.577	36547.863
Government Grant (Non-Development)	15332.979	20893165	36226.144
Self Generated Funds	1770.089	10595.925	12365.954
Tution Fees	0.000	14955.688	14955.688
International Research Grants	125.709	429.781	555.490
Donations / Endowments (Govt.)	166.366	757.745	924.111
Donations / Endowments (Private)	3.099	4519.156	4522.255
Others	10.620	3591.301	3601.921
Total	**43039.088**	**66660.338**	**109699.426**

Table 1-2: Total S&T Spending in Millions of Rupees, by Source (2007-8) (Source: PCST 2009)

Another important feature of R&D funding is its variability across sectors over the years. While universities have flourished in the recent years, this cannot be said of other elements of Pakistan's STI system. With some notable exceptions, public sector S&T organisations have experienced a considerable period of neglect vis-à-vis both human resource development and research support.

An example of this underfunding is agricultural R&D. A 2005 report on the state of the country's National Agriculture Research System (NARS) painted a picture of tragic decline in agriculture R&D between 1980 and 2000. In 1980-1, the total research expenditure of PARC was PKR 40.4 million, including 11.1 million (27%) of non-development and 29.3 million (73%) of development funding.[72] In 2000-1, these figures stood at PKR 330.5 million, PKR 305 million, and PKR 25.5 million, respectively. While this represents a secular increase in nominal terms, the expenditures (in particular, the development funds) have not kept pace in real terms. For instance, the funding for PARC's research programmes stands at PKR 68.2 million with a non-development component of PKR 63 million and a development component of only PKR 5.2 million.[73] The trend is quite similar, although not as stark, for total (development and non-development) agricultural R&D expenditure.

The total agricultural R&D expenditure in China, India, and Pakistan stood at 1.174 billion, 746 million, and 223 million (in constant 2005 dollars) respectively in 1991. These same figures were 2.574 billion, 1,355 billion, and 171 million respectively in 2002 – registering a change of +119%, +82%, and -23.3%.[74] With Pakistan's fortunes tightly coupled with the fate of its agricultural economy, these numbers must be of serious concern for science and economic development planners alike.

1.4.3 A new funding structure

Despite recent improvements in the funding of STI, at 0.67% (2007-8) Pakistan still lags considerably in funding of R&D as a percentage of GDP compared to international norms (approximately 1.5-3%). It is difficult to develop a clean breakdown of different types of R&D funding in Pakistan due to proliferation of different funding structures, funding streams, and classification systems within large public sector bodies. However, it is quite evident that there are serious imbalances in the manner S&T is funded in Pakistan, most notably, an over-emphasis on basic and applied research rather than development, innovation and commercialisation; and on public rather than private funds.

Addressing these gaps will require a re-thinking of the funding structure for science and innovation within the country. It will require a re-alignment of current STI funding streams and the creation of new ones; redefining the missions of several existing public entities and re-alignment of incentive structures; and attracting private sector participation in the STI system through better incentives and public private partnerships.

1.5 Outputs from the STI system

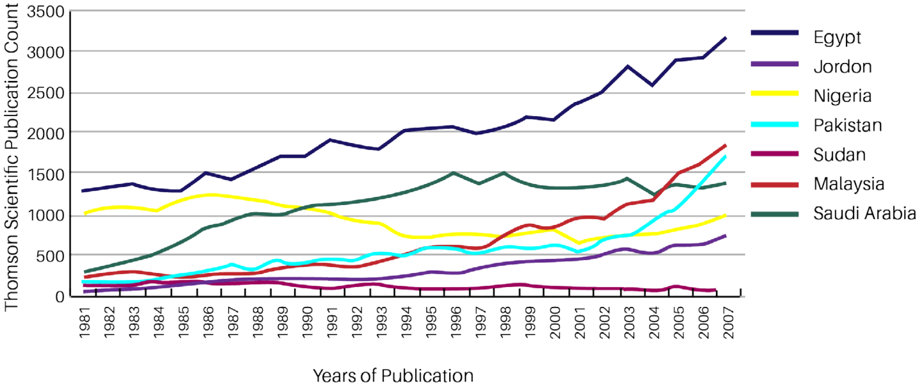
1.5.1 Publications

In recent years, there has been a serious policy drive towards encouraging scientific publishing . HEC has prioritised publications in high impact factor international journals in its performance assessment framework. A tenure track system (TTS) within public sector universities and a Research Productivity Allowance (RPA) scheme to reward publishing has resulted in a significant increase in the number of papers published by Pakistani scientists and researchers from within and outside Pakistan.

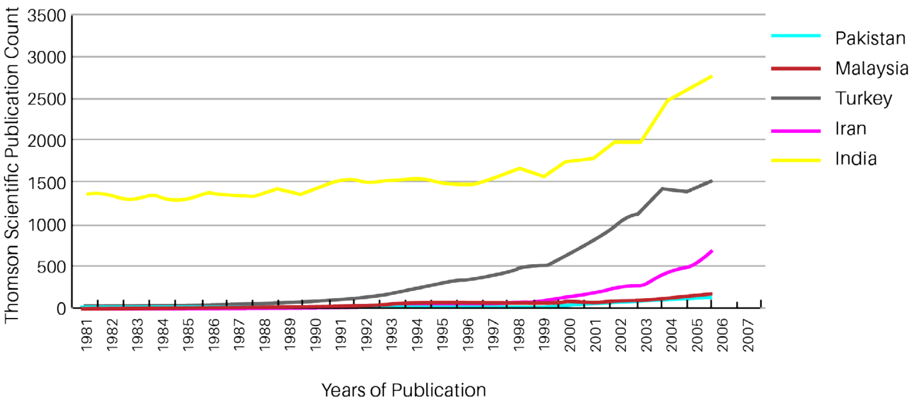
Buoyed by this new impetus in publishing, Pakistan has gained considerably vis-à-vis international competition even though it started from a smaller base and despite the fact that it spends a relatively smaller absolute and per capita spend on R&D than comparable countries.[75] During the 1980s and early 1990s, the performance of Pakistan, Malaysia, Sudan, and Jordan were similar with Pakistan doing only marginally better. Since 2003, Pakistan has caught up with Malaysia even though the latter's increase in publications precedes Pakistan's by almost 6-7 years (see figure 1-9). In recent years, though, Malaysia has seen considerable increase in scientific publishing by its own scientists likely leaving Pakistan behind once again.

Despite these recent developments, there is a considerable room for improvement and catching up to do when one compares Pakistan's performance against some of the leading

OIC member countries (such as Turkey and Iran) and other developing countries (such as India, South Africa, and Brazil).



Annual Publication Rates for Selected Muslim Countries (1981-2007)



The Catch Up: Annual Publication Rates for Selected Muslim Countries (1981-2007)

Figure 1-9: Pakistan's publishing performance against selected countries (Source: Thomson Reuters)

1.5.1.1 Traditional Strengths in Pakistani Science

Pakistani authors published 22,205 papers during a five year period between 2004 and 2008 (see figure 1-10)[76]. The top five areas in which these papers were published include medicine (4,204 papers, 19%), agriculture (2,713 papers, 13%), engineering (1,778 papers, 7.98%), chemistry (1,724 papers, 7.74%), and physics and astronomy (1,662 papers, 7.46%). Some of the leading institutions publishing during 2004-08 are listed in table 1-3.

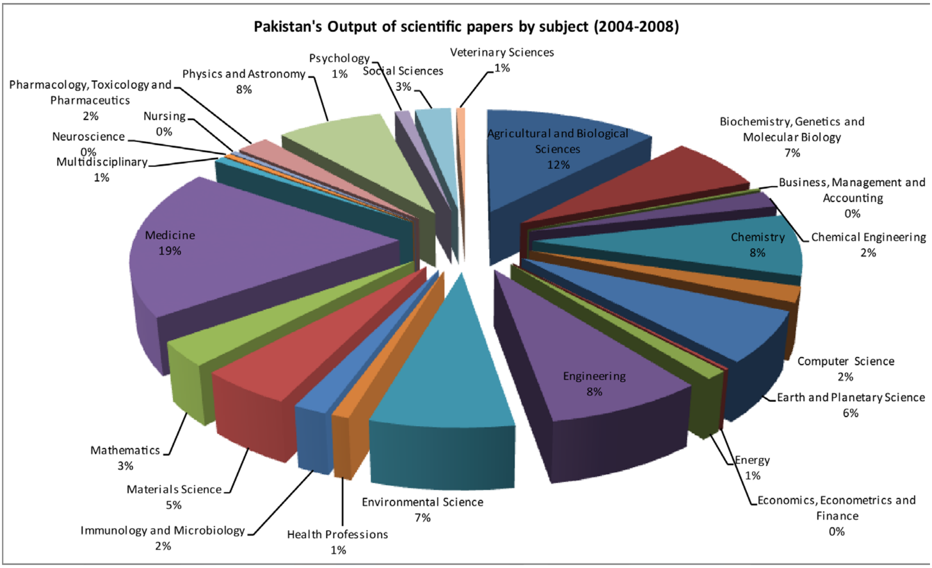


Figure 1-10 Pakistan's output of scientific papers by subject (Elsevier Data, 2004-2008)

Institution	Article Count	Citation Count	Collabo-ration	Impact
Quaid-e-Azam University (QAU)	1633	3934	70%	2.409
University of Karachi (KU)	1433	2374	60%	1.659
The Aga Khan University (AKU)[77]	847	1454	38%	1.717
The Aga Khan University Hospital (AKUH)	823	3027	55%	3.678
University of the Punjab (PU)	759	1220	62%	1.607
Pakistan Institute of Nuclear Sciences and Technology (PINSTECH)	577	1458	71%	2.527
University of Agriculture (UAF)	515	1547	56%	3.004
COMSATS Institute of Technology	415	1071	74%	2.581
Government College University (GCU)	398	739	74%	1.857
PCSIR Laboratories (PCSIR)	344	396	60%	1.151

Table 1-3: Top-10 Leading Publishing Institutions in Pakistan (Elsevier Data, 2004-2008)

1.5.1.2 Bright Spots and Emerging Areas

This data points towards new and emerging areas where Pakistan did not traditionally have a strong research base but where one has been developing in recent years. These areas include material sciences (1,054 papers, 4.73%), mathematics (699 papers, 3.14%), and computer science (437 papers, 1.96%), which corroborates with the nomination of Pakistan as a 'rising star' by Thomson Reuters' ScienceWatch in these, and several other disciplines.[78]

Other potential bright spots of Pakistani research include environmental science (1,654 papers, 7.29%), biochemistry, biotechnology and genetics (1,511 papers, 6.78%), chemical engineering (459 papers, 2.06%) and immunology (382 papers, 1.72%). Considerable amounts of research money have funded the development of research capabilities in biotechnology and genetics[79] and medical and immunology[80] during the 1990s and 2000s, respectively.

Paper Title / Partial Title	Journal Title	Pakistani Author	Number of Citations
How many child deaths can we prevent this year?	The Lancet (2003)	Z. Bhutta (AKU)	596
Allergic Rhinitis and its Impact on Asthma	Allergy (2008)	Y. Mohammad (Allergy and Asthma Institute)	494
Human mitochondrial DNA deletions	Nature Genetics (2001)	Tariq M. (PIMS)	323
Maternal and child under-nutrition	The Lancet (2008)	Z. Bhutta (AKU)	322
Prevention of diarrhea and pneumonia by zinc	Journal of Pediatrics (1999)	Z. Bhutta (AKU)	321
Measurement of the atmospheric neutri-no-induced	Physics Letters (1998)	B. C. Choudhary (PIN-STECH)	302
Ultrasensitive Electrical Biosensing of Proteins and DNA	Journal of American Chemical Society (2004)	M. R. Jan (Peshawar)	2924
Evidence-based, cost-effective interven-tions	The Lancet (2005)	Z. Bhutta (AKU)	278
Monitoring Expression Profiles of Rice Genes ...	Plant Physiology (2003)	M. A. Khan (NARC)	274
No health without men-tal health	The Lancet (2007)	A Rahman (Inst. Of Psychiatry)	263

Table 1-4 Top-10 Cited Papers with Authors of Pakistani Affiliations (Elsevier, 1996-2008)

1.5.1.3 Quality and impact of research

The increase in the number of scientific publications in Pakistan has often been used as an indicator of the success of the country's recent higher education reforms (see table 1-5). There is little doubt that the number of publications in Pakistan has increased several fold during the last decade due to HEC's efforts to provide basic infrastructure for research in the universities and significant research funding. There is a clear increasing trend in publications and citations for most disciplines except social sciences (see 5.4.1) and business and management where performance declined (see Table 1-5). While Pakistan has made considerable ground in catching up in terms of both publications and citations, with the exception of mathematics where an average Pakistani paper is cited 20% more than world average, Pakistan has a long way to go before it can begin punching at its own level in a variety of scientific disciplines.

	Pre- Reform (1998-2002)			Post-Reform (2003-07)		
	Total Papers	% of World	Relative Impact*	Total Papers	% of World	Relative Impact
Biology and Bio Chemistry	134	0.05	- 77.5	282	0.09	- 60.9
Chemistry	725	0.14	- 75.9	1,582	0.26	- 71.3
Computer Science	9	0.02	- 75.9	1,582	0.26	- 71.3
Economics and Business	16	0.03	- 81.3	17	0.03	- 88.5
Education	6	0.05	- 66.0	7	0.05	- 64.2
Engineering	165	0.06	- 55.9	518	0.14	- 10.1
Mathematics	27	0.04	- 70.2	66	0.08	20.8
Physics	409	0.09	- 58.9	729	0.14	- 44.9
Plant and Animal Science	474	0.21	- 68.8	863	0.34	- 67.6
Social Sciences	67	0.05	-12.9	117	0.07	- 27.9

Source: Science Watch / Thomson Reuters .
*Percentage a paper is cited more or less thanan Average paper in the discipline.

Table 1-5: Trends in Pakistan's performance in international publishing (Source: Nature, 2009)

A broader question also needs to be addressed about whether research funded by tax payers' money must have an impact beyond publications and citation. Translating research results into socio-economic and commercial benefits is where Pakistan, not unlike other developing countries, has lagged behind (see chapter 4).

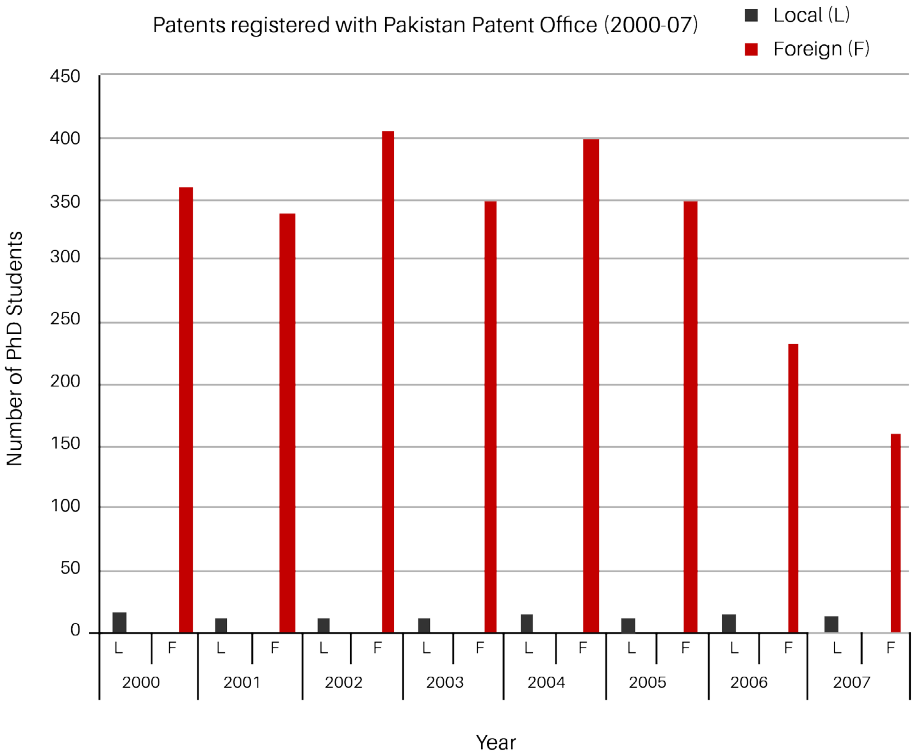
1.5.2 Other measures of impact

Beyond the debate on publications and citations, there is also a wider debate to be had about what precisely are the right indicators of scientific and innovation impact. "In recent years, we have moved away from [of scientific and technological] competitiveness towards measures such as publications and number of scientists", says Dr. Kamal Munir, a professor of innovation and strategy at Cambridge University's Judge School of Business. "However, while Pakistan has just caught up with Malaysia in terms of number of publications and is ahead of India in number of researchers per million of population, yet it lags far behind both these countries in technological development," he adds.

One particular measure of practical impact of scientific research and technology development could be patenting, though it is neither necessary nor a sufficient condition for such an impact to happen. The nature of innovation has been in a state of flux over the years and increasingly more "open" and "collaborative" models are a norm. This has made patenting an imperfect measure, at best.[81]

Pakistan lags considerably behind other comparable peer countries in terms of patenting. The absolute number of patent applications in Pakistan remains very low and most belong to foreigners or institutions with foreign roots, such as multinational companies (see figure 1-11). They have not shown an increase in the recent years. Due to enforceability and cost, amongst other reasons, the patent count may not accurately reflect the degree of innovation in Pakistani society in the same manner as it may do so in a developed country. PCSIR is the only institution that has pursued patenting with some measure of seriousness. It has developed more than 1600 processes, filed 507 patents and commercialised 130 technologies.[82]

Figure 1-11: Patent registers with the Pakistan Patent Office (2000-2007) [NEED TO BE REDONE]



Source: Intellectual Property Organisation of Pakistan, 2009

While science is an important ingredient to innovation, it may not underpin all innovative activity within a society. Two other kinds of innovations (and their likely impacts) merit a brief mention here. First, the importance of technological innovation that often entails reverse engineering and learning-by-doing has been well documented in literature and a number of South East Asian economies such as South Korea, Taiwan, and to some extent

Brazil, Mexico, and Turkey have deployed this approach as a cornerstone of their development strategies.[83] This was a particularly salient feature of Pakistan's developmentduring the 1960s and 1970s in developing the engineering and heavy industries. Second, studies have also pointed the importance of innovation with the non-technological realms – such as organizational, business model, marketing, design and logistical – as important drivers of firm and economic productivity.[84] There is a considerable history of such innovations in the Pakistani society – although these have not been formally documented and studied in equal measure.

It is difficult to conclusively capture the impact of these various types of innovation or isolate these without a significant econometric exercise and this report does not attempt to do so. However, it does identify a number of different types of innovations – including marketing, business model, social, and organisational – and present some anecdotal evidence of the same.

Considerable advances have been between 1950s and 1970s in developing a framework for industrial development through technological innovation (in particular, reverse engineering and learning) and, in recent years, in Pakistani science, although the latter have been largely limited to the higher education and university-based research. There is clearly an opportunity for Pakistan to build upon what has been created and this will require a holistic view of the entire STI system. Quality and relevance must be the attributes foremost in the minds of Pakistan's science policymakers, planners, and managers.

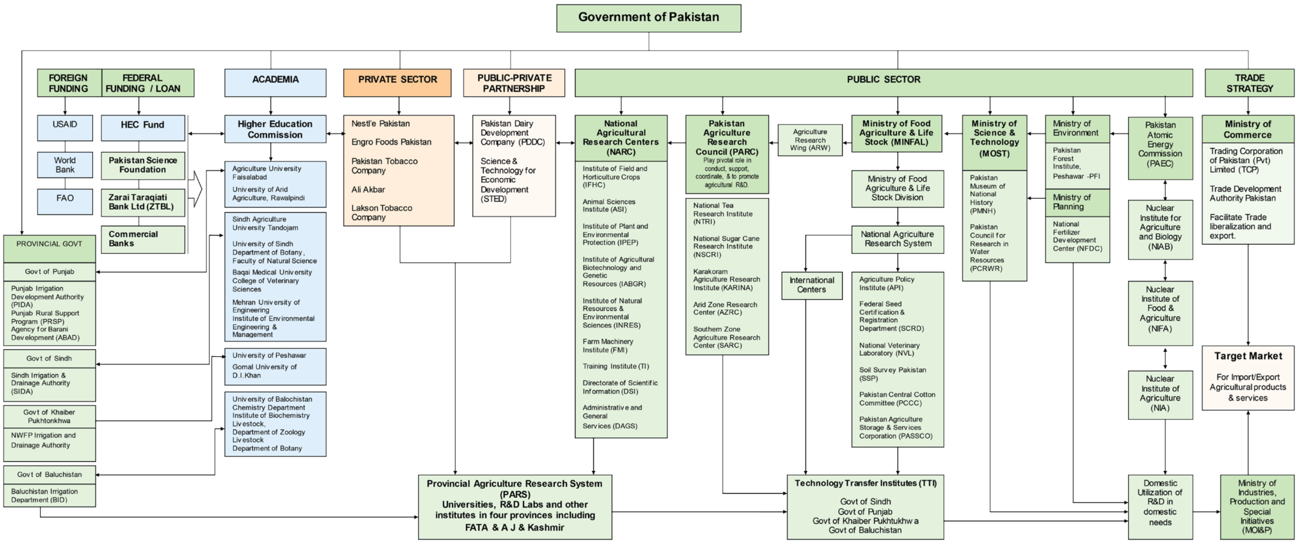
While Pakistani science must aspire for global recognition through quality scholarship, a clear argument can also be made for the need for science to deliver value to society in which it operates and from where it seeks to get its financial support from. These issues are explored in more detail in later chapters.

Textbox 1-5: Integrated Case Study: Mapping Agricultural Science and Innovation System

Agriculture and animal sciences has played the role of the country's economic backbone. Significant efforts and investments have gone into this sector over the last six decades and the outcome is a substantial infrastructure for innovation and development as mapped in Exhibit A. Viewing this map in the light of innovation ecosystem presented in Figure 1 (Introduction and Summary) reveals the many organizations and systems that have been established – at various levels almost entirely in the public sector – to realize policy development and implementation, infrastructure development, R&D, commercialization, and agriculture extension services. These are complemented by academia and private sector. As with other sectors in Pakistan, and elsewhere in the world, this presents challenges.

In the institutional make-up, one can easily see the hodgepodge of ideologies, policy initiatives, strategic priorities, temporal needs, and turf-centric interests and sometimes notice its impact as well. Dr. Iftikhar Ahmad, the former Director General of National Agriculture Research Centre (NARC) notes that "two out of ten new crop varieties developed at public R&D organizations actually get to the farm". "Our dairy sector", notes Prof. Mohammed Nawaz, the former Vice Chancellor of University of Veterinary Sciences (UVAS), "is the fourth largest in the world and yet suffers from extremely low yields due to poor farming practices." Dr Iqrar A. Khan, the Vice Chancellor of University of Agriculture Faisalabad (UAF), the sub-continent's oldest agriculture university, believes our agriculture STI system is broken and nothing short of a radical redesign is needed to fix it.[85]

A streamlining of priorities combined with greater focus on large-scale capacity upgradation through public-private partnerships can deliver quick and substantial returns.



Sources:

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Official Website of Higher Education Commission
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Official Website of Ministry of Industries, Production and Special Initiatives

Public Organization
Academia
Private Organizations

Figure 1-12: Mapping Entities Involved in Agriculture Sector of Pakistan

2. People

With a population of 180 million people, Pakistan is the world's sixth most populous country and the second (after Indonesia) in the Islamic World. Its growing population is increasingly putting a strain on its resources and ability to deliver employment, quality of life, and material well-being to its people.

Yet, Pakistan's people need not be its liability but can become its most precious assets. Pakistanis are some of the world's most talented and hardworking people. Pakistan is the country of Professor Abdus Salam, the Nobel Laureate; of Mahbub ul Haque, the founder of Human Development Index; of Jehangir Khan, the unbeaten King of the game of squash; Imran Khan, one of cricket's greatest all-rounders; and Abdus Sattar Edhi, the philanthropist who created the world's largest private ambulance network.

The challenge is to cultivate this asset into a skilled and innovative workforce working within the context of a proper institutional framework to drive socioeconomic development. This chapter begins by exploring Pakistan's educational system and then turns to other human capital priorities that need to be addressed.

2.1 An educational emergency

In 2009, Pakistan's literacy rate (defined as the ability to sign one's name in native language) was 57% (69% for males and 47% for females). Literacy remains higher in urban areas (74%) than rural areas (48%); higher among boys (69%) than girls (45%); and higher in some regions than others (59% in Punjab compared to 45% in Baluchistan, for example).[86]

Despite these advances in literacy, the goals of universal education in Pakistan remain elusive. With seven million primary-aged children still out of schools, Pakistan is far from achieving its international obligations under the Millennium Development Goals (MDGs) and Dakar Framework for Action for Education for All (EFA). Co-chaired by Dr Michael Barber, Head of Educational Practice for McKinsey & Co and former Advisor to Tony Blair, a Pakistan Education Task Force (a coalition of federal and provincial governments as well as civil society) has compared the crisis facing Pakistan's education system with any other national emergency, including the earthquake of 2005 and floods of 2010.[87]

2.1.1 Building on weak foundations

Whereas the 'educational pyramid' of a more developed country builds on a stable and wide base, Pakistan is built on weak foundations. Approximately a third of Pakistani children simply do not enter primary school. The remaining two thirds experience a significant attrition as children progress through the educational system. 56% complete primary school (grade 5); 41% make it to middle school (grade 8); and 25% through to high school (grade 10).[88] Only 6% of those in the educational pipeline complete graduation.

One major problem is the quality and number of schools in Pakistan. Schools, typically, tend to be overcrowded with high student-to-teacher ratios, and uninspiring places that promote rote-learning. Although, privately funded schools have mushroomed into almost an industry, the relatively better quality ones are still beyond the reach of the middle classes. Many

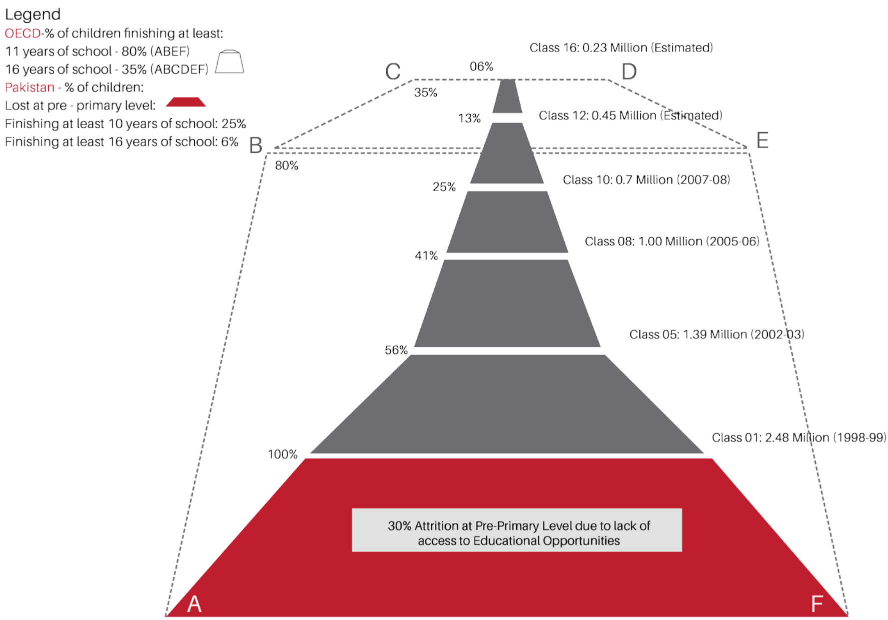


Figure 2-1: Pakistan's edu cational pyramid[89]

Catholic schools provide decent education at affordable prices and have developed reputations for delivering well-rounded, quality education. Where the state has abdicated its responsibility, non-profit and private providers have sought to fill the gaps, especially in rural areas (textbox 2-1). However, Dr Anita Ghulam-Ali, founder of the non-profit Sindh Education Foundation (SEF) has warned that (i.e. private sector provision) 'this is not necessarily the solution to government's failure'. Despite numerous examples of many other noteworthy NGOs, they collectively do not even represent 1% of the total solution. In 2007-8, Pakistan had more than 225,000 educational institutions at various levels, of which more than 170,000 were in rural areas, serving more than 33 million students across the country.[90]

2.1.2 Funding basic and primary education

A second major problem is the allocation and use of funds for basic and primary education. The majority of funding allocated for basic and primary education is made at the provincial and district levels (PKR 82.4 billion and PKR 142.3 billion in 2009-10, respectively). The relatively low funding for basic and primary education at the federal level has given rise to some objections and controversies, especially when compared to the levels of federal funding for higher education.[94] The arrival of the HEC has raised questions about whether the right balance is being struck between various levels of the education system.

Textbox 2-1: Non-governmental efforts to fill educational gaps

Established in 1995, the Citizens Foundation (TCF) is Pakistan's largest NGO, operating more than 660 schools and providing education to around 92,000 students almost half of whom are girls.[91] The US based Developments in Literacy (DIL) works with partner organisations in Pakistan to operate 149 schools with more than 15,633 students across rural Pakistan.[92] Other NGOs have chosen to adopt schools already running under state provision. Created in the aftermath of the 1988 floods, the Care Foundation today operates 192 schools with an enrolment of 145,000 students and a staff of more than 4,300 teachers across Pakistan. In 1998, through a landmark public-private partnership the Care Foundation adopted its first schools being run by the City District Government of Lahore. By 2003, the Care Foundation had adopted and was operating more than 131 schools in this district.[93]

In 1992, the Sindh Education Foundation (SEF) was created by the Government of Sindh to undertake educational initiatives. Starting with a meagre budget and no infrastructure to show for it, SEF today manages a budget of over one billion rupees (though still a small fraction of Sindh's education budget of Rs 60 billion) and a staff of 164 people. SEF has been a trendsetter in educational innovation, leading to the creation of National and Provincial Educational Foundations in other provinces.

As the then Senator and current HEC Chairman, Dr Javaid Laghari is on record, on the floor of the Senate, lamenting the state of education in Pakistan when he said: "Failure: yes, we are a nation of drop-outs and failures ... what this country needs is a Lower Education Commission, not a Higher Education Commission. We have 21 pages of budget on higher education, but only four pages of budget on education"[95]. This criticism, however, is not entirely valid since education is a provincial responsibility and the federal allocation alone is not a full measure of overall educational funding (see table 2-1).

In 2009, the Government launched a New Education Policy. Whilst acknowledging the progress that had been made in improving gross and net enrolment levels within Pakistan (the latter increasing at the primary level from 57% in 2001-2 to 60% in 2005-6 and 70% in 2007-8)[96], it also identified two major causes of poor performance.[97]

On the one hand, there is a 'commitment gap'. Pakistan continues to spend a relatively small proportion of its resources on education in terms of percentage of GDP. In 2009, Pakistan's public sector expenditure on education was only 2.1% of GDP compared with 2.6% in Bangladesh, 3.5% in Indonesia, 4.7% in Malaysia, and 5.1% in Iran.[98] Nevertheless, more than PKR 300 billion allocated to education at various levels of government in 2009-10 (see table 2-1) is still a significant amount of money when compared with other needs, such as, the approximately Rs 450 billion that Pakistan spent on defence in the same year.

On the other hand, there is the 'implementation gap'. A significant proportion (20-30%) of the funds allocated to education remains unspent each year.[99] This 'implementation gap' suggests that the inability to deliver comprehensive quality basic and primary education may not only be a result of the lack of political support for doing so. It may also be due to an inefficient use of resources that has pervaded the educational system, especially in rural areas where ghost schools and absentee teachers are widespread.[100]

Promisingly, the New Education Policy committed to increasing the share of GDP allocated to education to approximately 7% by 2015, whilst also reaffirming the responsibility of the provincial and local governments to promote universal primary education by 2015 and secondary education up to grade 10 by 2025.[101] It envisages a different approach whereby educational policymaking and its implementation become truly national, rather than federal, matters. An Inter Provincial Education Ministers' Conference with representation of all the federating units has been proposed to oversee progress in this area.[102]

Federal Government	**Current**	**Development**	**Total**
Ministry of Education	3,718.665	5,500.000	9,218.655
Higher Education Commission	21,500.000	18,500.000	44,000.000
Federal Government Education Institution in Cantonment and Garrisons	1,929.760	14.910	1,944.670
Federally Administered Tribal Areas	4,143.716	1,534.318	5,678.034
Gilgit Baltistan	1,408.738	784.081	2,192.819
AJ&K	3,794.450	722.000	4,516.450
Social Welfare & Special Education Division (DG SE and PBM)	410.340	316.450	726.790
National Vocational & Technical Education Commission	226.000	1,500.000	1,726.000
Other Federal Ministries/Divisions/Organizations	6,570.556	3,663.33	10,233.89
Total (Federal)	**43,702.222**	**32,535.090**	**76,237.312**
Provincial Governments			
Government of Punjab	24,778.707	24,794.589	49,573.296
Government of Sindh	13,919.081	6,020.000	19,939.081
Government of Khyber Pakhtunkhwa	2,411.730	2,421.133	4,832.863
Government of Balochistan	2,008.985	6,059.354	8,068.339
Total (Provinces)	**43,118.503**	**39,295.076**	**82,413.579**
District Government**			
Punjab	66,223.058	6,293.739	72,516.797
Sindh	31,930.127	5,714.157	37,664.284
Khyber Pakhtunkhwa	21,379.271	1,995.678	23,374.949
Balochistan	8,673.374	102.460	8,775.834
Total District Governments	**128,205.830**	**14,106.034**	**142,311.864**
Total Provinces & District Governments	**171,324.333**	**53,401.110**	**224,725.443**
Grand Total Federal, Provincial & District Governments	**215,026.555**	**85,936.200**	**300,962.755**

** : Tentative Statement* *Source: Ministry of Education*

*** : Provisional data based on projection*

Table 2-1: Public sector allocation to education in 2009-10[103]

2.1.3 The teaching crisis

A third source of problems is the lack of qualified teachers that can deliver quality at basic, primary and secondary education. Creating a cadre of high quality school teachers requires high quality faculty at the universities. Retaining the latter in turn requires transforming Pa.

kistan's universities into exciting centres of learning and discovery. "It is this logic that has underpinned HEC's recent investments in higher education", says Dr. Mahmood H. Butt, the former Vice Chancellor of Allama Iqbal Open University (AIOU) – Pakistan's first distance education university. "Without providing quality education in the universities at both graduate and undergraduate levels, it is impossible to create a cadre of better qualified teachers necessary for any reform at the basic and primary level", he adds.

Professor Pervez Hoodbhoy has been a vocal critic of this approach. An MIT graduate and formerly a professor of physics at Quaid-e-Azam University (now at Forman Christian College University), he has taken upon himself the role of being the conscience of Pakistan's academic and scientific community. Provocative and often controversial, Hoodhoy is one of the most astute and critical social commentators on Pakistani science and education. 'Pakistani university and college students, as well as their teachers, are far below the internationally accepted levels in terms of basic subject understanding', says Hoodbhoy. To Hoodbhoy, the rationale for producing a large number of PhDs is misguided and unlikely to have an impact on basic and primary education. He instead believes that large numbers of quality (science) teachers will only be delivered through creating teacher training colleges across the country. He suggests creating 'large-scale teacher training academies in every province... with [an expense of]...perhaps a billion dollars over five years'. A cadre of education managers and education leaders is also necessary to implement education reforms throughout the hundreds of thousands of schools across Pakistan.

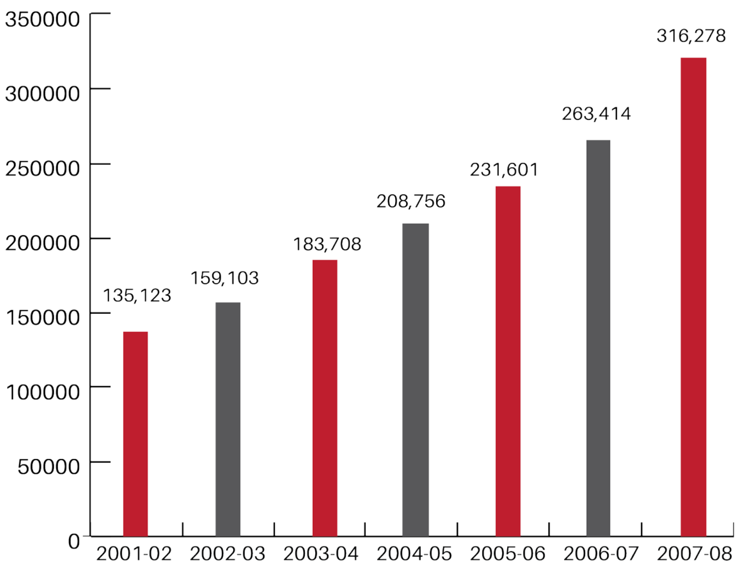


Figure 2-2: Enrolment in universities from 2002-02 to 2009-08, excluding distance education
Source: HEC, 2010; Academy of Educational Planning and Management, 2012

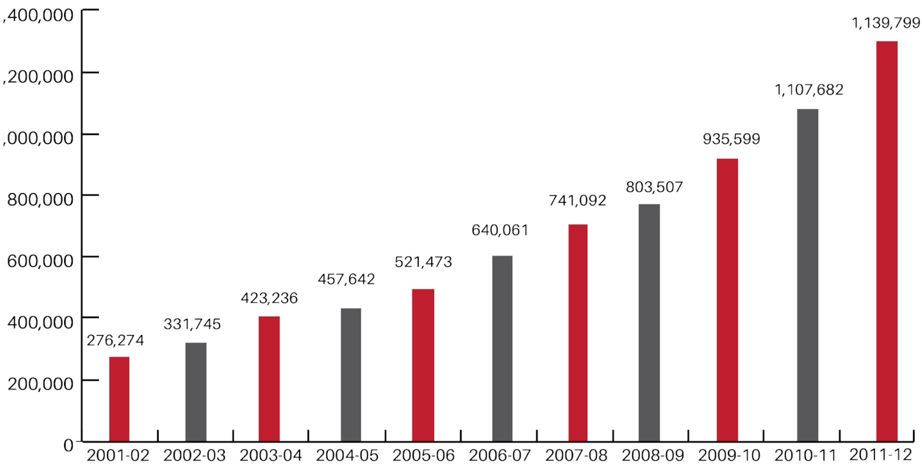


Figure 2-3: Enrolment in universities and Constituent Colleges 2001-2 to 2011-12
Source: HEC, 2010; Academy of Educational Planning and Management, 2012

2.2 Higher education

In recent years, higher education is the part of the educational system that has received the greatest attention in Pakistan. During the last decade, the number of universities has almost doubled to now include 73 public sector and 56 private sector universities. Since 2001-02, the enrolment in universities has more than doubled from 135,123 to over 316,000 in 2007-8 (see figure 2-2).

2.2.1 The rise of the HEC

Since 2003, the HEC has embarked upon an ambitious effort to create scientific manpower primarily in public sector universities and particularly through PhDs in natural sciences, computer sciences, information technology, and engineering. More than 2700 foreign PhD scholarships were awarded and a programme of creating 5000 indigenous PhDs was initiated. There have been concerns about the quality of PhDs produced by local universities. Nonetheless, collectively these programmes have re-energized the pipeline of scientific manpower within the country with more than 8000 or more PhDs expected over the next 3-5 years. In addition to manpower development, HEC has launched many different programmes seeking to create a good research environment, directly support research, inculcate innovation, and improve access.

HEC's efforts have generally been welcomed by the universities' leadership and academic community and the related investment has helped create an opportunity for Pakistani universities to begin engaging meaningfully with the global scientific enterprise. Not all of the HEC's programmes have been equally well designed or successful.[104] HEC has been criticised for carrying out deep reforms in a heavily centralised manner, thereby undermining universities' academic freedom and institutional autonomy.[105] Criticisms have been raised about the effectiveness with which HEC has spent money during its first five years from 2003 to 2007. Accusations have been made that HEC has wasted resources,[106] and created perverse incentives within the higher education system.[107] HEC's programmes have sometimes been accused of compromising the quality of research at the expense of quantity.[108] HEC denies each of these allegations and maintains, for instance, that universities were autonomous to suggest development projects whose implementation was then carefully monitored by its Monitoring Department. Till date, no systematic scientifically rigorous study exists to assess the impact of various HEC programmes on quality of higher education. However, these criticisms notwithstanding, the overall impact of HEC's initiatives has been very positive in give boosting to the cause of higher education in Pakistan.[109]

Given their earlier focus on teaching routine concepts and a low percentage of faculties with meaningful research and industrial experience, most Pakistani universities are only now beginning to think about addressing the needs of industry. In most cases, the universities and industry sectors have yet to develop the needed trust and motivation to collaborate. In 2005, HEC launched a University-Industry Interaction programme to 'establish a strong foundation of linkage between academia and industry of Pakistan'.[110] The programme has yet to deliver the desired benefits. However, there are signs that this is beginning to change (see section 4.6).

2.2.2 Pakistan's Universities

For much of Pakistan's 60 years, universities have largely been no more than glorified colleges focussed on teaching rather than research. They have undergone considerable change over the last decade and a difference in aspirations and ambitions is beginning to be felt. Most well established, and some newly established, universities are beginning to take research as a serious activity even if some are struggling with the initial obstacles of expecting quality research from their existing faculty that had not done research for years, if not decades. Many others are taking their first steps at creating a tradition of quality research. There have been hiccups, including a few cases of plagiarism that were reported and some were effectively addressed by HEC. Overall, the progress nevertheless remains in the right direction.

Publication rates of Pakistani Universities have considerably improved over time with Quaid-e-Azam University, Karachi University, Aga Khan University, University of the Punjab and University of Agriculture Faisalabad (UAF) leading the way.

HEC carried out a peer-review ranking exercise in 2006 in which a large number of universities did not fare very well. The ranking Universities ranking exercise has since been carried out in 2010 and 2013 and while there is a secular improvement in rankings many universities continue to not do very well. A number of Pakistani universities have, however, begun to feature in international rankings and there is a general desire to seek international recognition through these ranking exercises. The National University of Sciences and Technology (NUST) was ranked 366th overall in QS World Universities Rankings in 2010 and 274th in Engineering and IT. University of Engineering and Technology Lahore was ranked 281 in engineering sciences.[111] A number of other universities would probably qualify should they seek to participate in these exercises.

Textbox 2-2: Pakistan's leading universities in natural and applied sciences

Established in 1983 by Prince Karim Aga Khan (the spiritual leader of the Ismaili Muslim community) to 'promote human welfare through research, teaching and community service' Aga Khan University (AKU) was Pakistan's first private sector university. According to Dr Shamsh Kassim-Lakha, its first President, AKU 'has since set the standards in this country and beyond for quality, access, impact, and relevance to the local environment'. Today, AKU has campuses in Afghanistan, East Africa, Egypt, Syria and UK. AKU has carried out research in areas, including community health, HIV, tuberculosis, nutrition, neo-natal and pre-natal health. It led a global review by The Lancet of nutrition-related interventions to raise awareness in 36 countries where 90% of undernourished children live.[112]

Quaid-e-Azam University (QAU) is Pakistan's only graduate research university, offering only Masters, MPhil and PhD degrees. Established in 1967 and named after the country's founder in 1976, QAU is rated as one of the top public higher education institution in Pakistan. More than 80% the faculty holds doctoral degrees and many have worked or done post doctoral research abroad in renowned universities of the world. Among others, the university is particularly known for its research capability within the natural sciences, especially physics). QAU's Physics Department maintains strong international linkages with the German Academic Exchange Service (DAAD); ICAC Scheme of Abdus Salam International Centre for Theoretical Physics in Trieste Italy; International Program in the Physical Sciences in Uppsala, Sweden; as well as several international donors. Research areas of focus are nuclear and particle physics, plasma physics, lasers, and theoretical physics. Some of the most cited papers published by QAU faculty have appeared in Physics Letters,[113] Science,[114] International Journal of Engineering Science,[115] and Enzyme and Microbial Technology.[116]

Other leading universities, such as Karachi University and University of Agriculture Faisalabad are profiled elsewhere (see textbox 1-1 and textbox 3-1 respectively).

2.2.3 Engineering education

Pakistan has a long tradition of narrowly focussed engineering universities with the creation, in 1921, of what later became the University of Engineering and Technology (UET) in Lahore (formerly McClagen College) which has since produced more than 30,000 engineering graduates. Since then, UETs have been set up across provinces with at least one in each provincial capital. National University of Sciences and Technology (NUST) is an agglomeration of defence engineering colleges spread across the country. These universities have traditionally focussed on relatively more established disciplines of engineering, such as electrical, mechanical and chemical engineering.

More recently, a number of computer science schools, such as the National University of Computer and Emerging Sciences (NUCES) and COMSATS Institute of Information Technology (CIIT), have been set up to meet the growing demand of computer science graduates in the country. In 1993, GIKI became the country's first private sector engineering university and has since produced high quality engineering graduates. GIKI has been followed by the School of Sciences and Engineering (SSE) at Lahore University of Management Sciences (LUMS). For most of Pakistan's history, with some notable exceptions, the majority of these universities have focussed on producing graduate engineers to meet the operational and design needs of the industry with little emphasis on engineering research. This has slowly changed in recent years with relatively newer universities, such as GIKI, NUST, SSE at LUMS and others developing a greater research focus. The traditional UETs have been slow to change but the trend is unambiguously in the right direction.

In recent years, HEC has explored the ambitious idea of establishing a number of foreign-run Universities of Engineering Sciences and Technology of Pakistan in collaboration with major European and Asian countries at an estimated cost of $300 million each. This project was considered too expensive and risky to undertake simultaneously and thus failed to gain traction and was shelved.

Many of these universities are profiled in more detail elsewhere in the report (see Sections 4.5.1 and 4.5.3) and the state of engineering and IT industries are discussed as well (see Text Box 3, Section 4.5.1)

2.3 Other human capital priorities

2.3.1 Valuing technical and vocational training

Although supported by the Pakistani government in the 1950s and 1960s, technical and vocational training suffered during the nationalisation of industry in the 1970s and was in a state of a breakdown by the 1980s.[117] For the most part, the Pakistani government left the provision of this training to industry. Large companies set up their own in-house training programmes. This also became the norm in the public sector. The PCSIR Pak-Swiss Training Centre is an important exception known for its quality training and engineers who are taken up by industry in record time.[118] Another interesting example is a public-private partnership created in 1999 as the Technical Education and Vocational Training Authority (TEVTA), which established a unified structure of command for all technical and vocational institutes within Punjab. While the Authority's performance has still not been subjected to a rigorous review, a PCST Expert Committee on Technical Education recommended implementing similar structures across Pakistan's other provinces.

Today, the 58 polytechnics and technical institutions and over 700 vocational training institutions fall short of producing the quality output to meet Pakistan's growing needs.[119] One major barrier to developing a technical and vocational training system is a preference for while collar jobs and lack of appreciation for blue collar work.

2.3.2 Women and the STI workforce

The difference in the number of men and women enrolling in higher education has reduced significantly from approximately 63:37 (a difference of more than 20%) to 53:47 (a difference of around 6%) between 2002 and 2008, respectively.[120] Within the education system, women are as equally represented as men in certain disciplines, such as management, and even outnumber men in others, such as medicine and the arts.[121] However, challenges remain once women move into the workforce. According to PCST statistics, women constitute less than 30% of the more than 53,000 researchers in Pakistan, and only approximately 15% of the total STI workforce (when technicians and support staff are also considered). Of the stock of 5,300-plus PhDs, only approximately 16% are women. Women are also underrepresented in positions of senior leadership within academia, industry, business, and scientific institutions.

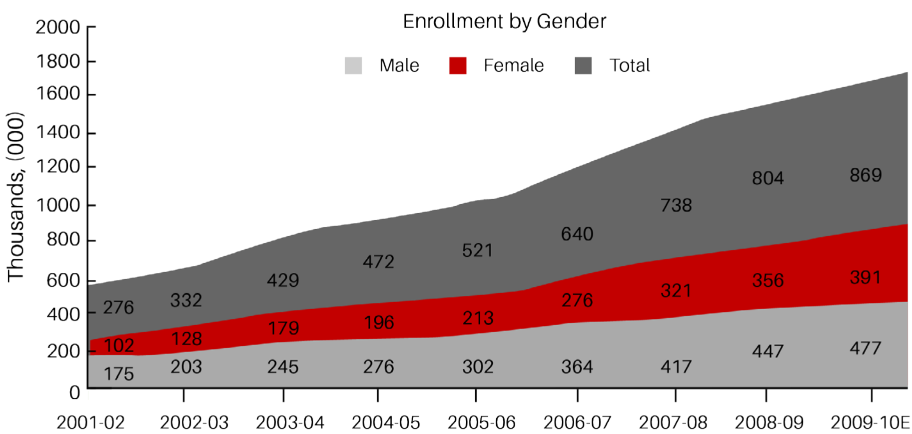


Figure 2-4: Gender wise enrolment in higher education institutes
Source: HEC, 2011

2.4.3 International recognition of scientific achievements

Promoting inspirational role models may be one way to start addressing this challenge. The UNESCO L'Oreal International Fellowships Programme has been awarded to Pakistani women twice during its ten year history. In 2004, Farzana Shaheen at HEJ Institute of Chemistry won the award for her work in natural products chemistry. In 2009, Ishrat Bano at Qauid-e-Azam University won the award for her research on drug delivery using nanoparticles.[122] In 2011, LUMS' Umar Saif was recognised as one of MIT Technology Review's 35 Young Innovators (TR35) for his work on cheap affordable bandwidth solutions for developing countries.[123]

These awards are part of a wider international recognition of recent successes due to the revival of investment in STI. Pakistan has, over the years, participated in a number of international Science Olympiads and has won awards. Pakistani students have been consistent performers at International Science Olympiads winning two Bronze Medals and Four Honourable Mentions in Chemistry (Japan), Biology (Korea), Physics (Croatia), and Mathematics (Kazakhstan) in 2010[124] and nine Bronze Medals and four Honourable Mentions in Biology (Taiwan), Physics (Thailand), Chemistry (Turkey), and Mathematics (the Netherlands) in 2011.[125] Two Pakistani girl college students won a third place from amongst 1500 scientists and innovators selected from 443 affiliate fairs in 65 countries in the Intel International Science and Engineering Fair (ISEF) in Los Angeles in 2011.[126] These international laurels and acknowledgements of the talent and creativity of Pakistani scientists will only increase with greater exposure and opportunities to compete.

There have also been arrangements to inspire and encourage young scientist and graduate students through interaction with leading international scientists and Nobel Laureates. Pakistan regularly participates in the Landau Meetings in Germany where each year 500-600 students from 50-60 developing countries meet with 15-20 Nobel Laureates over a week. Patterned along similar lines, a programme has been initiated to invite Nobel Laureates to visit and lecture in Pakistani universities. Two such programmes have been held and three international Nobel Laureates visited in 2006 (Geiever, Townes and 'tHooft) and 2007 (Agre, von Klitzing and Osheroff). An international meeting of young scientists also takes place at Nathiagali Summer College each year.

2.4.4 Engaging Pakistan's Diaspora

An estimated 7 million Pakistanis live across the world.[127] The largest communities live in United Kingdom, Saudi Arabia, United Arab Emirates, and United States of America. Through successive waves of migration, the Little Pakistans around the world - from Devon Avenue in Chicago and Jackson Heights in New York; to Gronland in Oslo and Green Street in London are testaments to the rich cultural diversity that Pakistanis have brought to their adopted homelands. Many continue to be a source of important material and intellectual wealth for Pakistan (also see sections 1.4.1.1 and 7.2.1).

Sir Anwar Pervez of the Bestway Group,[128] James Caan of Dragons' Den fame and founder of Alexander Mann,[129] Safi Qureshey of AST Research Inc. and Zia Chishti of Align Technologies Inc. are just a few examples of the many successful expatriate Pakistanis. Many of these individuals have made Pakistan a focus of their development and philanthropic work. James Caan, for example, created the James Caan Foundation to help the needy in UK and

Pakistan. He also works with the UK's Department for International Development (DfiD) to promote education in Pakistan.

In recent decades, the migrations from Pakistan have included scientists and academics. A number of these individuals working at US and European universities have sought to collaborate with counterparts and their institutions in Pakistan. Others have returned to Pakistan to establish new departments and relatively well-knit communities of expertise. Bringing with them new ideas and a passion to improve their country, these individuals have, in some cases, helped to create a new culture of change in Pakistan (also see sections 1.4.1.1 and 7.2.1).

Textbox 2-3: Integrated Case Study – Manpower for the Agriculture Sector

Total manpower in agricultural R&D, according to a PCST Census, comprises around 20,000 which include 7,269 researchers, 3,090 technicians, and 9.512 support staff. Agricultural researchers account for about 13% of the total research professionals in the country. Most work either in a public R&D organisation or in academia. However, the growing importance of the agriculture sector in Pakistan because of food security requirements in future,[130] lower current farm yields,[131] and shrinking land availability and utilization[132] requires innovate new ways of doing agriculture whether that be new crop varieties, water security, food security, land utilization, mechanization of cultivation, or management initiatives for improving farm yields. This in turn requires capable manpower to be deployed at each stage in the innovation supply chain of the agriculture sector.

In recent years, there has been a thrust from the Higher Education Commission to train a future crop of scientists and researchers for the sector particularly at University of Agricultural, Faisalabad (UAF) and National Institute of Biotechnology and Genetic Engineering (NIBGE). UAF represents the single largest concentration of PhD students in the country. Beyond the formal innovators i.e. the researchers and scientists who work at tens of different research institutes, agricultural research stations, and model farms to extend the boundaries of the possible, the agricultural sector need 'informal' innovators who introduce novel ideas in technology adoption, farmer education, supply chain management, and storage and distribution, among others. This is where the private sector can play a constructive role – particularly in training of technicians as well as through adoption of innovative downstream processes. The agricultural sector could also benefit from interest from the Diaspora communities who might become purveyors of money, new practices, and knowledge. Many of the innovations in agricultural and farm livelihood occur "informally" at the grass roots level and may benefit from a formal mechanism to study and replicate these across a wider geographical area.

Recently, Pakistan Agriculture Council (PAC) has been formed as an umbrella body of private sector interests in agriculture and food sectors with almost all leading private sector players participating. One of the areas where PAC seeks to make an impact are bridge training programmes for farm workers. PAC shall run a model farm where, quite similar to a doctor's house job, recent university graduates in relevant disciplines shall be provided a year-long hands-on apprenticeship in modern methods of farming and food processing thus enabling them to quickly bridge their gaps in learning and technology adoption and become useful for the sector.

3. Places

Spread over 796,096 square kilometres, Pakistan is a geographically diverse country from the warm waters of the Arabian Sea in the South; to the snow capped mountains of Hindu-Kush, Karakorum, and Himalayas in the North and North West; and deserts of Thar and Thal to lush green plains of Punjab. Pakistan is also blessed with rich natural resources, including the world's highest mountains and most fertile plains; the world's largest earth filled dam at Tarbela in the North West; one of the world's most comprehensive irrigation system in Punjab in the Centre, and substantial deposits of natural gas, coal, copper, and gold in the Southern and South Western provinces of Sindh and Baluchistan.

While chapter 1 described the Federal government's central role in Pakistan's national STI system, this chapter surveys the spread of STI capacity across its historical and geographical landscape through an analysis of the places where research is occurring and promising centres of innovation are emerging.

Figure 3-1 Map of Pakistan

3.1 Distribution of STI assets

Administratively, besides a number of autonomous regions such as Gilgit-Bultistan (GB) – formerly known as the Northern Areas and Independent ("Azad") Jammu and Kashmir (AJK) – and other territories, Pakistan is divided into four provinces: Punjab, Sindh, Khyber-PakhtunKhwa (KPK) – the province encompassing the north western region of Pakistan – and Baluchistan (see figure 3-1). Punjab is the largest province by population (45%) followed by Sindh (30.5%), KPK (11.6%), and Baluchistan (4.5%). Approximately 1.5% of Pakistan's population lives in the federal capital, Islamabad Capital Territory. When combined with the neighbouring twin city of Rawalpindi, this jumps to 2.5%.

3.1.1 Parity and disparities

Like any other federal democracy, the distribution of Pakistan's resources, including its STI assets, has been at the centre of political debate within Pakistan since its creation. Until last year, Pakistan's Constitution allowed the Federal Government the authority to legislate and regulate on S&T. This allowed the Federal Government to have considerably more influence than the provinces over the setting of S&T policy. In 2009, the Federal Government had the lion's share (70%) of overall national S&T expenditure, followed by private (20%), mostly university fees, and lastly the provinces (10%) (see table 3-1).

Province / Region	**Population Share**[133]	**Universities / Degree Awarding Institutions (DAIs) - numbers**			**S&T Expenditure (PKR, millions)**
		Public	Private	Total	
Federal	Included	14	3	17	74,668.65
Punjab	57.7%	20	16	36	7,874.72
Sindh	22.3%	13	25	38	2,402.22
KPK	14.2%	13	9	22	948.82
Baluchistan	5.7%	6	1	7	415.08
AJK	n.a	1	2	3	n.a
Northern Areas	Included	1	-	1	n.a
Private	n.a.	n.a	n.a	n.a	23,389.93
Total	177 million[134]	68	56	124	109,699.43

Table 3-1: Provincial share of S&T expenditure and Universities (Sources: PCST, 2009, HEC 2008)

The distribution of public universities favours the capital territory far more than any other province. More than 20% of all universities are based in Islamabad. With the exception of the Federal Capital, the role of the public sector has been to compensate the less populous of the provinces (KPK and Baluchistan) for lack of private sector interest in establishing universities. Sindh's deficit in public universities is made up by the contribution from the private sector (see table 3-1). A similar pattern may exist within individual provinces as well. In Punjab, for example, several population centres, such as Sialkot, lack appropriate university infrastructure.

The situation with public R&D institutions is a bit better since locations for many of these are dictated by natural endowments or historical factors. Exceptions do still exist where universities and a number of R&D organisations are not located in traditional population centres. The historical city of Multan in Central Punjab is home to the Central Cotton Research Institute that has carried out considerable work on Bt Cotton and Cotton Leaf Curl Virus.[135] A National Central Sugar Research Institute set up in the sugar growing area of Thatta in the interior of Sindh has developed a number of new sugar cane varieties as well as work on producing sugar from beetroot.[136] A National Tea Research Institute in the Shinkiari district of Mansehra in KPK promotes research on the indigenous development of tea plantation and processing industries. This Institute has set up tea nurseries and had 525 acres of tea under cultivation in 2005-6. The Arid Zone Research Centre is headquartered in Quetta in the Baluchistan Province. It focuses on livestock research and other arid zone agricultural products, such as wheat, barley and lentil.[137] Other institutions include a National Centre for Excellence in Geology at the University of Peshawar in KPK; a Farm Machinery Institute in Islamabad; a Sugar Crops Research Institute in Mardan in KPK; and a Mango Research Station in Multan in Southern Punjab.

3.1.2 Centre and the provinces

The strong tradition of federal control within the country is often resented by the provinces, smaller ones particularly. This is likely to change in the coming years and decades as the 18th Constitutional (Amendment) Act of 2010 enters into force, mandating the devolution of most ministries to provincial levels. In its May 2011 report, the 18th Constitutional Amendment Implementation Commission identified a number of adjustments. While large areas where the Federal government has dominated policy and implementation, (such as agriculture and industries) may be devolved, others may be shared between the provinces and the centre.

Two subjects that have become the shared responsibility of federal and provincial governments are national planning and national economic coordination, including the planning and coordination of S&T research and standards in institutions for higher education and research and scientific and technical institutions. These changes are likely to impact the STI policy and infrastructure in as yet unforeseen ways.

The coming months and years are likely to witness a civil society debate as well as, potentially, legal challenges between the central and provincial governments about the extent and manner of the impending devolution. For example, significant gaps may exist in provincial capacities to develop and implement policies across a range of relevant areas. Regardless of the outcome, they have the potential to bring about a considerable reshaping of the country's STI landscape.

This tension has already come to a head, once, over the battle of devolution of the HEC to the provinces.[138] In early 2011, a government-backed Constitutional Implementation Committee ordered the closure of HEC at the Federal level and the devolution of its functions to provincial ministries.[139] Only after the Supreme Court's intervention and considerable political pressure has the Government been forced to reconsider its position.[140] Over the years, the support for HEC has fluctuated considerably and the final verdict on the future of higher education with or without the HEC is not yet in.

3.1.3 Other disparities

A number of different sources and studies suggest that approximately between 32 and 35% of Pakistanis lived below the poverty line ($1.25 per day) in 1999.[141] More recent figures from the Human Development Index (HDI) suggest a declining incidence of poverty at 22.6% (compared to 41.6% in India and 49.6% in Bangladesh).[142] The same source puts about 60.2% of Pakistan's population living at under $2 per day.[143] Poverty is a crushing burden for Pakistan and it is clearly a hindrance to the development of a robust scientific milieu in the country. Social mobility becomes an even complex issue because access to literacy and education are also related to poverty. The urban and rural divide is yet another complicating factor. Though the benefits of science and access to education are freely available in urban settings, life in rural settings is still quite basic (see section 2.1.1). While literacy and poverty may be a bottleneck for most Pakistanis to carry out scientific activities, many in the country still enjoy the benefits provided by science and technology. Internet is quite ubiquitous thanks to a government policy and programme a decade ago to bring it to over 1000 villages across Pakistan. Mobile phone penetration is one of the highest in the world (more than 100% for the population over a certain age).

3.2 The nucleus of Pakistan's agricultural heartland

The National Institute of Biotechnology and Genetic Engineering (NIBGE) was established in the late 1980s as part of the government's efforts to promote the emerging disciplines of biotechnology and genetic engineering. Although not stated as such, one of the primary reasons for creating NIBGE was the search for a second agricultural revolution in the country. So it came as no surprise that the choice of location for NIBGE fell on Faisalabad, Central Punjab, the birthplace of Pakistan's first agricultural Green Revolution.

3.2.1 Birthplace of the Green Revolution

In the 1960s, philanthropy by the Rockefeller Foundation allowed Norman Borlaug, an American agricultural scientist, to travel to the sub-continent and address the descending droughts. Borlaug had spent years at the International Maize and Wheat Improvement Centre (CIMMYT) in Mexico developing high-yield dwarf wheat varieties. He began planting these in the sub-continent in 1965 and achieved dramatic improvements in productivity by the end of the 1960s. Borlaug had perhaps the most formative single influence on Pakistan's Green Revolution, reversing food shortages that had haunted the country in the 1960s.[144] While many in the Pakistan's agriculture establishment took it from there and without whom things would never have moved on, Borlaug's impact was pivotal earning him a Nobel Peace prize in 1970.[145]

There are a few key lessons to be learned if a second Green Revolution is to be possible.

First, the potential of science to deliver national objectives was appreciated, prioritised, and adequately funded. Second, the various components of the agricultural STI system from education to research and extension worked in effective coordination with each other. Inputs were not limited to academia but included applied research in public sector laboratories; extension services designed to introduce new wheat varieties; new methods of sowing and managing crops; innovation in irrigation methods; mechanisation of farming as well as organisational changes in agricultural practices.

Unfortunately these lessons have been subsequently lost on successive Pakistani governments and agricultural R&D has shrunk considerably over the years. 'Whatever research has been carried out', says Dr Iftikhar Ahmed, the former Director General of the National Agricultural Research Centre (NARC), 'has been foreign (donor) funded. There is little value that our governments have attached to research beyond funding the salaries of staff. This is not enough to carry out coordinated research programmes like the past'. The challenges of the future may be even larger than the past. Vice Chancellor of University of Agriculture, Faisalabad, Pakistan's premier institution for agriculture research, Dr Iqrar A. Khan warns that 'A second agricultural revolution will require greater coordination between education, research, and extension services in the country's agriculture sector than is currently possible'.

Textbox 3-1: Delivering a second Green Revolution

As a focal point for Pakistan's biotechnology, NIBGE will have a central role to play in a second Green Revolution. It is one of the several biosciences institutes of PAEC, the others being Nuclear Institute of Food and Agriculture (NIFA) and Nuclear Institute of Agricultural Biology (NIAB). NIBGE has five research divisions in agricultural biotechnology, health biotechnology, industrial biotechnology, and environmental biotechnology, and one providing technical services. Key areas of research include the development of GM crops, especially to address Cotton Leaf Curl Virus.

One of the challenges for NIBGE is to take the work of the Nuclear Institute of Agriculture and Biology (NIAB) a step further to help Pakistan meet its target of 20.7 million bales of cotton envisioned in the country's Cotton Vision 2015. Established in the late 1960s, NIAB has a successful track record of research. It was responsible for the NIAB-78 variety of cotton that led to cotton production in Pakistan increasing from 3 million bales in 1983 to 12.8 million bales in 1991-92, contributing significantly to economic development within the country.[146] Since the mid-1990s, Pakistan's cotton output has stagnated due to the recurrence of diseases and pest attacks. A major part of the solution is to introduce locally developed, genetically-engineered variety of cotton with resistant qualities, such as Hvt Cotton that uses toxins from the venom of the Australian Web Spider to keep pests away.[147]

A number of other organisations will also need to play their part, such as the Ayub Agricultural Research Institute and University of Agriculture Faisalabad (UAF). Located a few miles away from NIBGE, UAF was established in 1906 and is one of the largest universities in Pakistan, it provides critical manpower for the agricultural sector with nearly 12,000 students and 660 faculty members, including 72 full professors. Throughout its history as a university, UAF has produced 854 PhDs and more than 23,000 Masters and Bachelors students. The University produced 969 papers last year, and has signed 67 MoUs with foreign institutions.[148]

3.2.2 Knowledge City

Dr Anwar Nasim, one of the early influences in shaping Pakistan's biotechnology drive in the 1990s, has called for designating Faisalabad as Pakistan's first 'Knowledge City', although the proposal has not received much support from successive generations of the country's political leadership.

NIBGE, Nuclear Institute of Agriculture and Biology, UAF and Ayub Agricultural Research Institute are not the only major players in Faisalabad. The city is also home to the country's first, and only, National Textile University. Faisalabad has the unique distinction of having the country's largest concentration of PhDs, as well as, some speculate, a billion dollar' club of the captains of the country's textile industry, which makes up the lion's share of the country's foreign exchange earnings (see section 4.1.1).

3.3 The defence and strategic industries corridor

3.3.1 Nuclear success

The region around the Cantonment City of Rawalpindi in Northern Punjab is home to Pakistan's strategic and defence industries. They have received the most significant support and attention of every Pakistani government. Like the Green Revolution, Pakistan's (civilian and military) nuclear programme is an unqualified success story. It, too, demonstrates how science can deliver national objectives – even under international pressures, sanctions and isolation – if prioritised at the highest levels of decision making and is adequately funded (see textbox 3-2).

On the military front, PAEC and the defence establishment achieved major breakthroughs to join the world's exclusive nuclear weapons club. Key accomplishments include the indigenous development of centrifuges to enrich uranium; diagnostic equipment to measure nuclear tests results; as well as detonation and delivery systems.

Textbox 3-2: Key nuclear players in Pakistan

On the civilian front, the most sig nificant achievement of scientists at the Pakistan Atomic Energy Commission (PAEC) has been the mastery, with little or no foreign support, of the complete nuclear fuel cycle for the Canadian-designed CANDU Pressurised Heavy Water reactor at the Karachi Nuclear Power Plant (KANUPP). It is the only reactor in the world that continues to operate without the support of the vendor.[149] PAEC scientists and engineers have worked closely with international vendors to completely overhaul the obsolete computers, controls, instrumentation systems of the power plant in 1998. In southern Punjab, PAEC is responsible for operating 300 MW Chashma I and Chashma II nuclear power plants established with Chinese collaboration. A possible third and fourth reactor again with Chinese support are currently being constructed.

Pakistan's first swimming pool-type research reactor (PARR 1) is based at the Pakistan Institute of Nuclear Sciences and Technology (PINSTECH) at Nilore near Islamabad. PAEC scientists refurbished and enhanced its capacity from 5MW to 10 MW. In doing so, they redesigned the reactor core so that it could use lower levels of enriched uranium rather than the original 90% highly enriched uranium.[150] Another 30 kW tank-in-pool type research reactor (PARR 2) was added at PINSTECH. Besides research uses, these reactors also supply radioisotopes for domestic use in medical applications. Increasingly, PINSTECH is seeking to export these radioisotopes abroad. Through PINSTECH's teaching arm, the Pakistan Institute of Engineering and Applied Sciences (PIEAS) and the KANUPP Institute of Nuclear Power Engineering (KINPOE), PAEC's has successfully developed indigenous training programmes to support its nuclear industry.

3.3.2 Defence successes

Along the highway from Rawalpindi to the frontier city of Peshawar in the Khyber Pakhtunkhwa (KPK) province lies the Pakistan Ordinance Factories (POF) – a key building block of Pakistan's defence assets. Created in the 1950s, POF is often considered the mother of the various defence R&D organisations that have sprung up since. The1970s witnessed increasing investments to develop indigenous capabilities, leading to the creation of HMC and Heavy Industries in Taxila, and Pakistan Aeronautical Complex in nearby Kamra (see section 1.1.2).

Outmatched in numbers on its eastern flank, Pakistan has tried to acquire or produce, if necessary, state of the art weaponry. In a dynamic similar to Pakistan's nuclear programme, frequent sanctions by Western countries, especially United States, strengthened the resolve to develop indigenous defense capabilities. Innovation has primarily been in establishing credible manufacturing capabilities to acquire and then reverse engineer weapon systems to adapt, extend and upgrade their capabilities (see textbox 4-2). Pakistan still has some way to go before it could either establish design or fundamental scientific capabilities, although it is moving in that direction.

Today, Pakistan has developed various weapon systems, including the Al-Zarrar main battle tank (a variation of Chinese T-59 and T-69 technology); armoured personnel carriers; Baktarshikan anti-tank munitions; Jasoos unmanned aerial vehicles; Mirage and F-6 rebuilds; Karakorum-8 and Super Mushshak trainer aircrafts; Agosta 90-B submarines; and Joint Fighter multi-role fighter aircrafts. Although much of this has happened with international, particularly Chinese, French, and Italian collaboration, these developments represent a significant step in building the capacity of Pakistan's defence industry. In addition, Pakistan has a fairly robust missile development programme, including several generations of liquid and solid fuel rocket systems, short-to-medium range delivery capability for conventional and nuclear warheads, and guided and cruise missile capabilities.

3.4 A centre of culture and rich historical traditions

While the Lahore Museum is eerily silent, the artefacts at Doha point towards Lahore's history of science and innovation. The 'Art in Science' exhibition at the Museum of Islamic Arts in Doha, Qatar, has a collection of a number of scientific artefacts, mostly Planispheric Astrolabes, produced in Lahore and the surrounding regions during the Moghul era. One of the most remarkable is a seamless Celestial Globe produced during the eighteenth century in modern day Lahore. Depicting a three dimensional map of the stars, it was uniquely produced as a single sphere rather than two hemispheres fused together. The commentary to this artefact notes that this ancient craft does not exist anymore.

As Dr Imran Ali, an economic historian and the Director of Karachi School of Business and Leadership KSBL), notes, 'Lahore was a brimming city of half a million people with a lavish infrastructure and luxury lifestyles in the early eighteenth century much before many of the European capitals of today even became cities'. Political events caused a mass exodus of artisans and big traders in the mid-eighteenth century, spreading this Diaspora into the neighbouring region that has created a mini economy that forms Pakistan's industrial heartland.

Today, Lahore is a burgeoning city of around 10 million people, making it the second largest city in Pakistan and one of the 30 major metropolises of the world and even though it may have lost the highly unique crafts of its golden years, a new geography of innovation is fast emerging. Among other things, Lahore is an emerging centre of gaming, animation, and mobile applications development industry in Pakistan. A number of companies – such as GameView Studios, Mindstorm Studios, TinTash, and GeniTeam, among others – that based in Lahore create an emerging and formidable cluster of this fast growing industry.

3.5 A vibrant industrial innovation triangle

The triangle formed by the three cities of Sialkot, Gujranwala and Gujrat-Wazirabad is a dynamic and entrepreneurial industrial cluster and is home to Pakistan's light engineering industry where Pakistan has traditionally made a name for its electric fans, surgical instruments, sports equipment, domestic appliances, ceramics and sanitary fittings, water pumps and electric motors.

Sialkot is a classic example of an economic cluster that came into being because of a series of historical accidents. Legend has it that a British man broke his tennis racquet in the latter part of the nineteenth century and, unable to find an immediate replacement, gave it to a local craftsman to fix it. By 1895, the city was famous for its tennis racquets and had started making cricket balls and bats from imported willows and leather by early twentieth century. A similar incident helped jumpstart the surgical instruments industry in the early twentieth century.

In keeping with its history of unplanned evolution with little government support, Sialkot also built a Rs 2.6 billion private-sector funded and managed airport- the first in Pakistan.[151] There were plans until a couple of years ago to work with a consortium of Swedish universities to build a foreign university in the city. Forward Sports, a leading sports manufacturer, collaborated with Loughborough University in the UK to develop a new soccer ball for Adidas. Forward Sports demonstrated formidable innovation under extreme pressure to create Brazucca – the official football of the FIFA World Cup 2014. The ball has been made of six polyurethane panels which have been thermally bonded; the reduction in the number of panels is claimed to increase the consistency in the ball. However for every Forward Sports, there are tens of companies that have been less successful. It is in these areas where Pakistan has substantial existing industries where innovation and an upgrading of capacity could make a significant difference to the country's economic fortunes. Nonetheless, Sialkot's Chamber of Commerce is eager to work with other entities to help upgrade the technical abilities of its SMEs and cottage industries.

For hundreds of years, Gujranwala has housed metal workers that shaped this city as a hub of light engineering industry in the modern times. Salient products include electric appliances such as washing machines, fans, cooking ranges etc. as well as light engineering equipment such as water pumps and electric motors, More recently, the city has also evolved as a hub of ceramic furnishing and sanitary fitting industries that have successfully challenged imported brands available in the country. Gujrat and Wazirabad are known for their fan, surgical instruments, and cutlery industries and contribute significantly to the country's GDP.

3.6 The economic capital

Karachi, the 'city of lights,' is Pakistan's economic and financial nerve centre. With a population of approximately 18 million people, 90% of whom are migrants of various backgrounds, Karachi is Pakistan's only metropolis and one of the world's largest. Apart from the financial capital, the city houses textiles, shipping, automotive, entertainment, the arts, fashion, advertising, publishing, software development, and medical and pharmaceutical industries. The city's GDP stands at $78 billion in purchasing power parity terms.[152] Several locations within Karachi could themselves be considered mini-clusters of economic activity. The I.I. Chundrigar Road for financials, the Shahra-e-Faisal for IT, and several fringe areas of Karachi house agglomerations of textile, steel, pharmaceutical, and automotive industries. A new Textile City is being built near Bin Qasim to accommodate and promote the growing textile and garments sector. The city centre also houses headquarters of several of the largest television and print media houses in the country.

In many ways, Karachi is a city of stark contradictions. More than 60% Kararchiites live in Katchchi Abadis (shanty towns). Karachi's demographic mix is changing very rapidly, notes Arif Hassan – an architect, writer, and social activist. The male-female literacy gap is closing; divorce rates are skyrocketing; and women participation in labour force is increasing.[153] Karachi leads the country in creating a social climate that provides, perhaps more than other places, for much looser social controls that encourage independent-minded free thinkers essential to innovation.

Textbox 3-3: Integrated Case Study – Importance of Places in Agriculture

Place is of paramount importance in the location of economic activity, all the more so in agriculture which is extremely dependent on certain natural characteristics (such as climate, soil, water availability, etc.) of these places. Home to an incredible diversity of climate, topography, and natural resources from the lush green lands in central Punjab which houses the world's largest irrigation system around centred around five rivers (hence the name, 'Panjab' or the land of five waters), to arid lands in upper and lower Punjab, and the upper Sindh which is suitable for arid agriculture and cattle grazing, Pakistan provides an immense variety of possibilities for agriculture. Successive governments have done a fair job in putting in place necessary infrastructure to support the development and enhancement of these natural land endowments.

There are 44 R&D institutions[154] comprising 101 research centres that are involved in the development of forests, soil and water resource management for agriculture, fishery, and livestock.[155] A number of places stand out as comprising critical mass of expertise such as Faisalabad and Multan (28 research centres), Rawalpindi and Islamabad (18 research centres), Karachi (14 research centres), and Peshawar (7 research centres) and these lend themselves for becoming research hubs for major and minor crops, farming practices, machinery, chemicals, and forestry industries within the country. In addition, to capacity upgrading and innovation, new ways of collaboration and coordination among research hubs and centres would need to be established in order to fully leverage the diversity of and bring about focus in research activity within the country.

With the proud heritage going back to the country's first green revolution, important places in the country's agricultural heartland and institutions like NIBGE, AARI, NIAB, CCRI, PFI, UAF, UVAS, and UAAR are capable of playing even bigger roles in future.

4. Business

Some fifteen years ago, Asif Tariq captured the imagination of his countrymen by constructing a two-seater aircraft on his rooftop garage.[156] Nicknamed Al-Munir ("The Shining One"), it used only locally manufactured parts and a salvaged jeep engine. As he flew across Karachi's skyline, Asif dreamt of building an indigenous ultra light aircrafts industry. Yet Asif did not receive the necessary support to realise his dream. Today, Al-Munir stands on display at the Pakistan Air Force Air Museum in Karachi as a shining example of Pakistani inventiveness and resourcefulness. But as a museum artefact that never reached the market, it also signifies the lack of governmental and wider societal support for innovators and entrepreneurs.

'I believe Pakistanis can create globally successful companies,' says Mr Ken Morse, the Director of the MIT Enterprise Forum and a regular visitor to Pakistan. 'There is sufficient talent and determination among Pakistani entrepreneurs to make it happen. The only thing stopping Pakistanis to create a truly global success story is that they are too timid to dream big and to dare,'[157] he adds. While this may be truer of traditional sectors than IT, it is beginning to change in recent years.

This chapter discusses the size and scale of private sector innovation, entrepreneurship and R&D in Pakistan, as well as the major barriers to innovation and how they might be remedied. It identifies promising signs of entrepreneurialism in Pakistan. It also builds a case for certain remedial measures to the weak tradition of science- driven innovation.

4.1 The structure of Pakistan's economy

4.1.1 Composition

Pakistan's GDP stood at $236.6 billion in 2013.[158] In 2010, at $174.86 billion Pakistan was the 48th largest economy in the world, or 27th largest (at $464.89 billion)when adjusted for purchasing power parity.[159] Per capita income is $1089 (nominal) or $2,791 (PPP adjusted, 2010) (see Table 4-1).[160] The poverty rate in Pakistan (% of population living under $1.25 per day) was estimated to be 22.6% in 2010.[161]

Over the years, the structure of Pakistan's economy has changed from being largely agricultural to a strong service base. In 2010, agriculture and the service sector accounted for approximately 20% and 53% of GDP, respectively[162]. Agriculture remained a major contributor (24%) to the GDP and employs 48.4 percent of the labour force.[163] Livestock accounted for 53.2% of the total value added to the agriculture sector.[164] The per capita GDP (in purchasing power parity terms) has grown from $1,601 in 1999 to $2,538 in 2009.[165]

4.1.2 Trade competitiveness

Pakistan's exports stood at $24.46 billion in 2012-13 up about 18% from $20.62 billion in 2008. In 2008, Textiles were the major source (53.3% of the total) of exports especially raw cotton, cotton cloth, and yarn, followed by food (17.2%), manufacturing items (18.8%), including (in order of decreasing size) chemicals and pharmaceutical products, leather goods, jewellery, cement, sports goods, engineering goods, and surgical instruments; and petroleum goods (4.9%) (see table 4-1). On the high technology front, Pakistan exported about $275 million (or just 0.5% of total exports) primarily comprising software and IT products and services.

Pakistan's imports primarily comprise petroleum; machinery (including power generation machinery); chemicals; transport equipment; raw materials, such as iron and steel); chemical fertiliser; drugs and medicines; luxury goods and other high technology items (see table 4-1). The country usually runs a negative trade deficit that has been aggravated by the fluctuating price of oil in the international markets.

The Structure of Pakistan's Trade (2013-2014)

Exports:

		July-April			
	Particulars	(2012-13)	(2013-14P)	%Change	Absolute Change
	Total	20143.2	20997.5	4.2	854.3
A.	Food Group	3918.0	3945.7	0.7	27.7
	Rice	1589.6	1850.4	16.4	260.9
	Sugar	393.1	248.3	- 36.8	- 144.8
	Fish & Fish Preparations	255.8	292.1	14.2	36.3
	Fruits	340.6	399.0	17.1	58.4
	Vegetables	213.6	187.0	- 12.4	- 26.6
	Wheat	53.4	7.1	- 86.8	- 46.4
	Spices	55.1	44.6	- 19.0	- 10.4
	Oil, Seed, Nuts and Kernelx	28.0	76.7	174.2	48.7
	Meat & Meat Preparation	177.6	192.5	8.4	14.9
	Other Food Items	811.2	648.0	20.1	- 163.2
B.	Textile Manufaturers	10739.8	11437.6	6.5	697.8
	Raw Cotton	138.3	196.1	41.8	57.8
	Cotton Yarn	1860.5	1708.1	- 8.2	- 152.4
	Cotton Cloth	2224.0	2346.8	5.5	122.8
	Knitwear	1663.6	1842.1	10.7	178.5
	Bedwear	1468.2	1767.3	20.4	299.1
	Towels	645.0	624.5	- 3.2	- 20.5
	Readymade Garments	1470.8	1580.8	7.5	110

	Makeup Articles	480.8	552.1	14.8	71.3
	Other Textile Manufacturers	788.6	819.8	4.0	31.2
C.	Petroleum Group	6.2	601.3	9653.7	595.1
	Petroleum Products	5.7	58.6	919.4	52.8
	Petroleum Top Neptha	0.0	542.7	-	542.7
D.	Other Manufacturers	4227.6	3852.3	8.9	375.3
	Carpets, Rugs and Mats	96.8	106.8	10.0	9.7
	Sports Goods	268.5	286.1	6.6	17.6
	Leather Tanned	390.1	438.2	12.3	48.1
	Leather Manufacturers	463.2	519.4	12.1	56.2
	Surgical G. & Med Inst.	252.6	281.7	11.5	29.1
	Chemical & Pharma Pro.	636.3	962.7	51.3	326.5
	Engineering Goods	217.8	255.1	17.1	37.3
	Jewellery	1142.9	319.1	- 72.1	- 823.8
	Cement	468.7	415.0	- 11.5	- 53.7
	Gear & Gear Products	119.8	58.4	- 51.2	- 61.4
	All Other Products	170.9	210.1	22.9	39.2
E.	All Other Items	1251.6	1160.5	- 7.3	- 91.0

P: Provisional (Source: Source: Pakistan Bureau of Statistics)

Imports:

		July-April			
	Particulars	(2012-13)	(2013-14P)	%Change	Absolute Change
	Total	36665.0	37104.5	1.2	439.5
A.	Food Groups	3632.4	3423.2	-5.8	-209.2
	Milk & Milk Foods	112.4	132.4	17.8	20.2
	Dry Fruits	65.7	84.3	28.3	18.6
	Wheat Unmilled	0.0	107.2	-	107.2
	Tea	323.0	247.8	-23.3	-75.2
	Spices	57.1	71.1	24.6	14.0
	Edible Oil (Soyabean & Palm)	1759.1	1608.2	-8.6	-150.9
	Sugar	4.1	5.1	24.1	1.0
	Pulses	282.8	239.5	-15..3	-43.2

	Other Food Items	1028.2	927.6	-9.8	-100.6
B.	Machinery Group	4712.4	5176.1	9.8	463.7
	Power Generating Machines	818.5	850.4	3.9	31.9
	Office Machines	216.6	176.3	-18.6	-40.3
	Textile Machinery	306.7	489.9	59.7	183.2
	Const. & Mining Machines	122.3	209.7	71.5	87.4
	Aircraft, ships and Boats	577.9	738.9	27.9	161.0
	Agriculture Machinery	87.1	56.3	-35.4	-30.9
	Other Machinery Items	2583.2	2654.6	2.8	71.3
C.	Petroleum Group	12362.5	12205.5	-1.3	-157.0
	Petroleum Products	7766.5	7466.8	-3.9	-299.7
	Petroleum Crude	4595.9	4738.7	3.1	142.8
D.	Consumer Durables	1873.0	1933.6	3.2	60.6
	Road Motor Vehicles	1191.8	1017.6	-14.6	174.2
	Electric Mach. & Appliances	681.2	916.0	34.5	234.7
E.	Raw Materials	5079.1	5111.2	0.6	32.1
	Raw Cotton	752.6	515.9	-31.5	-236.7
	Synthetic Fibre	333.9	349.4	4.6	15.4
	Silk Yarn (Silk & Anti)	449.3	517.0	15.1	67.7
	Fertilizer Manufactured	498.6	584.3	17.2	85.7
	Insecticides	63.5	95.5	50.4	32.0
	Plastic Material	1151.4	1352.8	17.5	201.3
	Iron & Steel Scrap	545.1	589.1	8.1	43.9
	Iron & Steel	1284.7	1107.2	-13.8	-177.5
F.	Telecom	1284.9	1027.4	-20.0	-257.5
G.	All Other Items	7720.7	8227.5	6.6	586.8

P: Provisional (Source: Pakistan Bureau of Statistics)

Table 4-1: Pakistan's major exports and imports

Textbox 4-1: Innovation opportunities in key sectors

Agriculture

Other than the major innovations of the first Green Revolution, a number of interesting product and process innovations in this sector include the creation of a citrus hybrid called "Kinnow" attuned to Pakistan's climatic and soil conditions that contributes 95% of the country's citrus exports (primarily to Gulf countries); a research campaign to identify and protect the country's main cash crop from cotton leaf curl virus (CLCV); a number of agricultural implements such as drip irrigation and zero-till drill; and management innovations such as coordinated crop management programme and farmer field schools.

In recent years, the livestock sector has been a focus of innovation, primarily organisational innovations involving public-private partnerships. Nestle's 'dairy hubs' initiative in Southern Punjab has been a successful organisational innovation that is likely to be scaled up and implemented across the entire province. Similar initiatives have been undertaken by Engro Foods in Northern Sindh. The University of Veterinary and Animal Sciences (UVAS) is working with Nestle to educate farmers and implement research programmes designed to enhance the health, nutrition, and yields of animals. A foot and mouth disease vaccine developed at UVAS resulted in a saving of Rs.6 billion in 2003.

Textiles

This industry makes up the lion's share of the country's foreign exchange earnings. Pakistan is the world's 4th largest producer and 3rd largest consumer of cotton within the textile industry[166]. Textiles contributes 8.5% to GDP and 45% of the total manufacturing produce, employing 38% of the manufacturing labour force, and contributing 61% of total exports.[167] In 2008, only 30% of Pakistan's textiles exports were higher value garments. [168]This ratio is increasing and Pakistani textiles manufacturers have adopted more sophisticated manufacturing and management processes.

There are examples of significant innovation within the textile industry. They include Masood Textiles' innovative fabric finishes - product innovations – that have liquid repellent, sun protecting, and anti-microbial qualities and process innovations such as Al Karam's burnout printing and Bareeze's embroidered fabrics. Retailing and market innovations also exist, such as Bareeze's network of outlets, and national brands, for example, Chenab's ChenOne and Gul Ahmed's Ideas, are beginning to emerge. Branded design and textiles houses are a relatively new phenomenon as companies start to embark upon creating global brands. These examples notwithstanding, however, the textile industry has lagged behind in innovation and R&D remains informal and haphazard, at best. One particularly promising area ripe for product innovation is synthetic fabrics and performance textiles. However, the academic and research infrastructure is weak and would need to be developed.

Chemicals and pharmaceutical

The chemicals sector contributes significantly to the large scale manufacturing sector which accounted for 12.2% of GDP in 2009-10.[169] Similarly, the pharmaceuticals sector comprises about 500-400 pharmaceutical manufacturing units, including 25 multinationals, meeting 70% of the country's medicinal needs in 2010.[170] The cause of pharmaceuticals and chemicals innovation, in particular, can be advanced in Pakistan if the country could produce its own raw material for drug development. This is likely to require substantial public investment in building a naphtha cracker – a critical but capital intensive industry component that takes in a gaseous or liquid hydrocarbon feed like naphtha and produces simpler hydrocarbons such as ethane, ethane, and other olefins for subsequent downstream use in petrochemicals and pharmaceutical industry. A number of reports have made recommendations to that effect but affordability has thus far hindered such an investment.[171]

While much of the chemicals and pharmaceutical industry in Pakistan is contract manufacturing and does not focus on science and innovation, there have been some exceptions. For example, Samad Rubber Works' innovative rubber products (such as chemical weapons suits and anti-mine shoes); and Qarshi Industries' signature Johar Joshanda developed in collaboration with PCSIR used process innovation to create a successful product (see section 4.3.4.4). A number of medicines were developed at Lahore's Government College University (GCU), focusing on local disease variants, such as a recent development of cost-effective insulin to fight locally prevalent type-2 diabetes; and the experimental use of photodynamic therapy to treat skin cancers at Pakistan Institute of Engineering and Applied Sciences (PIEAS). Other pharmaceutical companies doing innovative work include Schazoo Zaka Labs, Amsons Vaccines and Pharmaceuticals Ltd., Getz Pharma, and Ferozsons Biosciences.

Healthcare services is another area where considerable room for innovations exists. In addition to Aga Khan University (see textbox 2-2), Skaukat Khanum Memorial Cancer Hospital in Lahore has set up a cancer registry to better understand local variants and causes of cancers.[172] The Institute of Nuclear Medicine and Oncology (INMOL) in Lahore has developed an indigenous capability to provide cancer treatment and is one of several centres run by Pakistan Atomic Energy Commission (PAEC) to serve the vast majority of cancer patients in the country. It has done it by providing efficient and cost-effective access to outdoor and indoor patient treatment facilities, clinical & radioimmunoassay laboratory, diagnostic radiology and state of art modern equipment for nuclear medicine and radiotherapy. Generally, though, healthcare sector research and innovation activity is sub-critical and suffers from lack of coordination, funding, and appropriate incentives.[173] Even where funding exists, such as through a Ministry of Health R&D fund, it does not have proper focus and effective utilisation.

4.1.2 Trade partners and relationships

Pakistan's leading trade partners include United States, China, UAE, and Saudi Arabia (see table 4-2). Pakistan has been a member of WTO since 1995.[174] Pakistan is a member of a number of trade groupings, including South Asian Association of Regional Cooperation (SAARC) and its proposed Free Trade Agreement (SAFTA), although its participation has been limited because of its strained relationship with India;[175] and the Economic Cooperation Organisation (ECO) alongside Turkey, Iran and seven other Muslim countries of Central Asia.[176] Pakistan has a number of bilateral Free Trade Agreements, most notably with China, and others are in the process of being negotiated, for example, with the Gulf Cooperation Council (GCC).[177] In the past, Pakistan has sought preferential access to US and European Markets to make up for the economic toll of the War on Terrorism and the consequences of recent floods in 2010, but has been afforded only limited or temporary concessions – the most notable one being the recently announced GSP Plus arrangement that was widely hailed to bring about an economic boom in the country.[178] This has not happened.

								July-March	
Country	**01-02**	**02-03**	**03-04**	**04-05**	**05-06**	**06-07**	**07-08**	**08-09**	**08-09**	**09-10***
USA	24.7	23.5	23.9	23.9	25.5	24.6	19.5	18.9	18.6	17.3
Germany	4.9	5.2	4.9	4.8	4.2	4.1	4.3	4.2	4.3	4.2
Japan	1.8	1.3	1.1	1.1	0.8	0.7	0.7	0.6	0.7	0.5
UK	7.2	7.1	7.6	6.2	5.4	5.6	5.4	4.9	4.8	5.5
Hong Kong	4.8	4.6	4.7	3.9	4.1	3.9	2.7	2.1	2.2	2.1
Dubai	7.9	9.0	7.3	3.3	5.6	1.1	0	0	0	0
Saudi Arabia	3.6	4.9	2.8	2.5	2.0	1.7	2.0	2.6	2.4	2.0
Sub Total	54.9	55.0	52.3	45.7	47.6	41.7	34.6	33.3	33.0	31.6
Other Countries	45.1	45.0	47.7	54.3	52.4	58.3	65.4	66.7	67.0	68.4
Total	100	100	100	100	100	100	100	100	100	100

Table 4-2: Major Exports Market (Percentage Share)

						July-March	
Country	**03-04**	**04-05**	**05-06**	**06-07**	**07-08**	**08-09**	**08-09**	**09-10***
USA	8.5	7.6	5.8	7.5	6.1	5.4	5.0	4.9
Japan	6.0	7.0	5.6	5.7	4.6	3.6	3.6	4.3
Kuwait	6.4	4.6	6.2	5.7	7.5	6.6	7.2	6.0
Saudi Arabia	11.4	12.0	11.2	11.4	13.4	12.3	12.3	10.2
Germany	3.9	4.4	4.7	3.9	3.2	3.8	3.8	3.7
UK	2.8	2.6	3.0	3.1	3.9	4.6	4.5	5.1
Malaysia	3.9	2.6	3.0	3.1	3.4	4.6	4.5	5.1
Sub Total	42.9	40.8	39.3	39.6	40.6	38.9	39.1	35.9
Other Countries	57.1	59.2	60.7	60.4	59.4	61.1	60.9	64.1
Total	100	100	100	100	100	100	100	100

Table 4-3: Major Sources of Imports

4.1.3 Foreign Direct Investment

Pakistan has had a difficult history of foreign direct investment (FDI) complicated by political instability and policy reversals, on the one hand, and geopolitical circumstances and the country's international image, on the other. Traditional sectors that have attracted FDI are oil and gas, communications, construction and industry. Telecommunications and financial services have experienced a boom recently, attracting considerable FDI primarily from other OIC member countries, such as UAE, Egypt and Oman. In 2010, FDI declined by more than 50% over the previous year with significant declines recorded in the telecommunications and financial services sectors, although other sectors, such as oil and gas exploration, communications, transport, remained steady.[179] The recent auction of 3G/4G spectrum by the Pakistan Government has been speculated to bring about another bout of significant investment in infrastructure and capability in the coming years and the existing mobile network operators (MNOs) scramble to upgrade networks and enhance capacity. Beyond the licensing fees, this may or may not happen.

Despite helpful government efforts to attract foreign investment, including appropriate tax holidays and incentives, significant bottlenecks remain. These include law and order and country's image, increasing cost of doing business, and probably a lack of market scale. The recent examples of telecommunications clearly illustrates that foreign investment will come, albeit primarily from OIC member countries, when there exists a compelling opportunity to tap a large market and make a good profit.

Foreign direct Investment in Pakistan has grown from $ 0.3 billion in 2001 to $1.5 billion in 2005 and a high of $5.2 billion in 2008 before tapering off again in 2009. Much of this investment has come into the telecommunications sector as infrastructure investment exploded. The five year average between 2004-8 has been around $3.3 billion. In recent years the FDI is likely to pick up again following the auction of 3G/4G spectrum.

4.1.4 Cost of doing business in Pakistan

Pakistan provides one of the best financial environments for business. For example, in the apparel manufacturing business, Pakistan is currently the least cost environment for US markets.[180] Pakistan provides the least productivity-adjusted cost for labour. It also provides better costs of electricity, rent and indirect labour as compared to India and China. According to the World Bank, Pakistan ranks 110th in a list of 183 economies for ease of doing business in the world (see table 4-4 for specific costs of doing business).[181] There has been considerable variation, and gradual deterioration, in certain elements of the index for Pakistan in recent years. For example, while Pakistan's overall ranking went down from 85th in 2010 to 106th in 2013 and 110th in 2014 cost of starting a business increased to 10.4%of the income per capita and cost of registering property increased to 7.7% of income per capita.

Over recent years, the costs of doing business have worsened in Pakistan. Pakistani businesses pay the largest cost of security in the region; rely on one of the poorest supplies of electricity in the region; draw on one of the poorest education systems; and suffer from one of the highest cost of financing.[182] The increased costs of security pose a significant challenge to the emerging ICT industry, in particular, and increased energy costs has eroded the competitiveness of the manufacturing sector.

	Pakistan	India	Sri Lanka	Bangladesh	China	Malaysia	Turkey
Rankings on the ease of doing business	110	134	85	130	96	6	69
Cost of starting a business (% of income per capita)	10.4	47.3	20.5	19.9	2.0	7.6	12.7
Cost of dealing with construction permits (% of income per capita)	190.4	2640.4	18.4	110.3	344.7	14.7	142.5
Cost of registering property (% of property value)	7.7	7.0	5.1	6.7	3.6	3.3	4.0
Cost of import (US$ per container)	725	1250	775	1470	615	485	1235
Cost of export (US$ per container)	660	1170	595	1075	620	450	990
Cost of enforcing contracts	23.8	39.6	22.8	66.8	11.1	27.5	24.9
Cost of closing a business (% of estate)	4	9	10	8	22	10	15

Table 4-4: Ease of doing business compared to the region and the OIC

Source: World Bank Doing Business Report, 2014

4.2 State of innovation in business

An analysis of Pakistan's major exports against worldwide export patterns highlights divergence between what the worldwide demand is and what Pakistan is able to export. This suggests structural rigidities in the country's economic and export base.[183] A major part of the problem has been the country's inability to increase the value-added element in its export mix. There have been some advances in the last decade through the export of leather goods, garments and jewellery. However, there has been a lack of focus on innovation, particularly science-driven innovation, as the driver of the country's export competitiveness in traditionally strong areas, such as light engineering, surgical instruments and sports goods.

4.2.1 Capacity to innovate and R&D expenditures

According to the World Economic Forum's Global Competitiveness Report 2013-14, Pakistan ranks 133rd in the World on global competitiveness, 111th in the World on Network Readiness, and 77th in Innovation with an innovation sub-index score of 3.13 out of 6.0 (see table 4-5). This lags considerably behind China (32nd)t), India (41st), Malaysia (25th), and Turkey)(50th).

Contributing factor	Bangladesh (0-6)	China (0-6)	India (0-6)	Pakistan (0-6)	Sri Lanka (0-6)
Innovation	2.54	3.89	3.6	3.13	3.49
Capacity for Innovation	3.0	4.2	4.0	3.7	3.8
Quality of Scientific Research Institutions	2.6	4.3	4.5	3.6	4.0
Company Spending on R&D	2.4	4.2	3.6	3.1	3.3
University-Industry Collaboration in R&D	2.6	4.4	4.0	3.2	3.0
Govt. Procurement of Advanced Tech Products	2.4	4.4	3.3	3.0	4.3
Availability of Scientists and Engineers	3.8	4.5	5.0	4.4	4.7
Utility Patents per Million Population	0	9.2	1.4	0	0.6

Table 4-5: Status of innovation compared to other countries in the region

Source: Global Competitive Report 2013-2014, World Economic Forum (http://gcr.weforum.org)

Contributing factor	Pakistan (0-6)	Egypt (0-6)	Iran (0-6)	Malaysia (0-6)	Saudi Arabia (0-6)	Turkey (0-6)
Innovation	3.13	2.8	3.2	4.4	3.9	3.5
-Capacity for Innovation	3.7	3.1	3.4	4.9	3.9	3.8
-Quality of Scientific Research Institutions	3.6	2.7	4.2	4.9	4.5	3.7
-Company Spending on R&D	3.1	2.5	2.7	4.6	3.9	3.1
-University-Industry Collaboration in R&D	3.2	2.6	3.3	5.0	4.5	3.9
-Govt. Procurement of Advanced Tech Products	3.0	3.0	3.5	4.8	4.6	4.1
-Availability of Scientists and Engineers	4.4	4.4	4.6	4.9	4.6	4.4
-PCT Patent Applications	0	0.6	0.1	12.1	3.3	6.6

Table 4-6: Status of innovation compared to other OIC member countries
Source: Global Competitive Report 2013-2014, World Economic Forum (http://gcr.weforum.org)

While Pakistan spends 0.7% of GDP on R&D, which is comparable to India (see table 4-7), very little of it is spent in the private sector and the output generated in terms of value added activities and exports is low. Majority of the R&D in high-technology may well be limited to defence and strategic industries, thereby failing to make an impact on the country's high technology exports.

	Pakistan	China	India	Sri-Lanka
High-technology exports (Billion US dollar)	0.188	336.988	4.944	0.108
High-technology exports (% of manufactured exports)	1.4	29.7	5.3	2.1
Research and development expenditure (% of GDP)	0.7	1.5	0.8	0.17 (2006)
Researchers in R&D (per million people)	152.1	1070.9	136 (2005)	93 (2006)

Table 4-7 R&D Spending in Pakistan compared to other countries in the region

Source: Trading Economics (2008 Data unless specified otherwise), 2010 (http://www.tradingeconomics.com)

Private sector firms in Pakistan have shied away from R&D without any major exception. Even in agriculture and plant sciences, one of the most important sectors of Pakistan's economy, private sector R&D contributed to approximately 9.43% of the total R&D expenditure in 2003.[184] The situation is not much different today. High technology exports comprised just 1.4% of Pakistan's total exports in 2008 of which of which about 75% comprised of software and IT services and products. This compares with 29.7% ($337 billion) and 5.3% ($5 billion) for China and India respectively. While examples of private sector R&D, in particular, and innovation, in general, have been few and far between, some notable exceptions do exist.

4.2.1 Exceptional innovators

4.2.1.1 The Packages story

Syed Babar Ali is the founder of Packages Ltd and iconic figure of business and entrepreneurship in Pakistan. The expansion of his business empire is in many ways a typical industrialist's story, although with some unique twists. Before Packages Ltd established its joint venture with Tetra Pak, it used to develop packaging material from wood and other related raw material. This was not viable given the relatively high cost of raw material in Pakistan. Packages developed a chemical process to use wheat straw as a raw material and then developed the whole supply chain to collect enough of it to make it commercially viable. His success has evolved into the Ali Group that includes a diversified conglomerate of industries that also include insurance and investment banking. As the instigator of setting set up LUMS, Babar Ali's story highlights the rich potential of individual Pakistanis to think and act innovatively.

4.2.1.2 Revolutionising the global chemicals industry

A spin-off of Exxon Corporation's fertiliser business in the subcontinent, Engro Chemicals Pakistan Ltd (ECPL) is one of the most visible corporate brands Pakistan has ever produced. A global shift in Exxon's strategy resulted in divesture of Exxon's business and created an employee buy-back opportunity. Executed under the leadership of the late Shaukat Mirza, this was, and has been, the most successful employee buy-out of a major corporation in the history of Pakistan's business.

To put ECPL on a growth trajectory, the company pulled together another ground breaking first that changed not only the fate of this company but possibly the chemicals business worldwide. ECPL conceived a daring plan to relocate existing ammonia and urea plants in Pascagoula Mississippi, USA and Billingham, UK, to Pakistan. This world's largest relocation project, comprising over 13,000 tons of equipment, piping, structure and modules, saved the company about one half to one third of the cost of buying a new plant and propelled its growth forward. The execution of this plan received acclaim within relevant business circles and professional communities. It revolutionised the capital-intensive chemicals industry by lowering entry barriers for a number of relatively capital-poor countries to enter this industry. A number of other countries, such as China, have since copied from Engro's recipe book. Asad Umar, ECPL's former CEO, continued to innovate and diversify this business long after Shaukat Mirza and his predecessor. Today, ECPL is a large conglomerate with subsidiary businesses in food, energy, chemicals and industrial automation.

Packages Ltd and ECPL are not alone. There are other examples of innovation success stories. DESCON Engineering Services, the Al-Tuwairiqi Group and Qadri Brothers (see textbox 1-3). Despite these individual successes, there are thousands of other Pakistani companies, big and small, that have not been able to grow beyond their original focus. Innovation, particularly science-driven innovation, is not a hallmark of Pakistani business organisations. Private sector R&D is almost absent in Pakistan.

4.2.3 Multinational interest in Pakistan

The majority of multinational companies operating in Pakistan primarily see the country as a market and so have sales and distribution and, to a lesser extent, a manufacturing hub (for example, in consumer products, light electronics, and pharmaceutical industry) in Pakistan. Multinationals have, by and large, not looked at Pakistan as an R&D destination. There is hardly any multinational R&D activity in the country. In this, Pakistan contrasts sharply with India, China, and Malaysia that have been able to attract multinational companies to set up R&D facilities.

A small but growing number of multinational companies have sought to leverage and capitalise on the talents and hardworking nature of Pakistan's people to further their global aspirations. Siemens Pakistan- one of only three Siemens companies (the other two being Siemens AG in Germany and Siemens, India)- became a leading corporate differentiator in Pakistan when it leveraged its presence in Pakistan to establish an SAP practice to serve Pakistan and other regional markets. In 2010, Siemens had over 350 SAP consultants that are supporting implementations across Pakistan and the Middle East.

NCR Teradata- a provider of database software, enterprise data warehousing, data warehouse appliances, and analytics services – with over 7400 employees in 44 countries established a Global Excellence Centre in Pakistan to serve their global market.[185] Teradata consultants from Islamabad provide high-end consulting services to clients around the world.

Several hypotheses may be advanced on the reasons of lack of multinational interest in Pakistan as an R&D destination. The intellectual property (IP) regime is often mentioned as a leading issue. The legal framework for IP protection does exist, although a data protection law does not; but the capacity to implement this framework, such as IP courts, has been a major challenge. On the other hand, the lack of an effective IP enforcement regime has not been a major problem for the ICT industry to develop products and software for international markets. However, as the domestic IT industry has matured through product innovation in the recent years, there has been a realisation of the importance of IP protection. It is expected that an indigenous IPR movement will evolve in the coming years and proliferate to other sectors of the economy as well.

Beyond these innovative companies, multinationals have played a considerable role in Pakistan's economic life. A number of multinational companies across a range of industrial sectors such as IT and Telecom (e.g. Google, Microsoft, Cisco, Intel, and Nokia), chemicals and pharmaceuticals (e.g. BASF, ICI, Ezko Nobel, GSK, Abbott, and Shell), electrical and electronics (e.g. Philips, Dawlance, and LG), consumer goods (e.g. Nestle, Lever Brothers, Reckitt – Benckiser and Colgate Palmolive) and automotive (Toyota, Suzuki, Honda, Kawasaki, and Yamaha) have been active in Pakistan.

4.3 Factors affecting business innovation

4.3.1 Management and ownership challenges

The majority of Pakistani businesses are run by families and tend to remain fairly closely managed affairs. They tend to function around the whims and aspirations of a particular individual (or a family). These businesses do not attract the kind of professional management and breadth and depth of vision necessary for continued and innovative growth. It is hard to find many examples of well-run businesses that have continued to perform well over decades and across generations. Due to a lack of healthy management transitions, they tend to stultify or disintegrate. 'The coupling of financial ownership and management', says Asad Umar, the former CEO of Engro Pakistan, 'is the key bottleneck in creating successful global companies from Pakistan. If you could ensure de-coupling of ownership from management, I could create ten Engros in Pakistan'." Engro Pakistan is the country's first successful employee-owned company that has grown from a couple of hundred million dollars to a several billion dollar company within a span of a decade.

4.3.2 Government policies

Government policies relating to the private sector have changed over the years, ranging from fiscal incentives for import substitution and indigenisation; to protectionism through heavy duty on imports; to access to subsidised capital and subsidies on production. Sustained periods of protectionism have often been counter-productive, leaving few, if any, incentives for businesses to improve the quality of their products, reduce costs, or innovate. Instances of inconsistent tariff policies on raw materials and finished products have been common over the decades, and have sometimes resulted in destroying value-added industry in the country. For example, there have been instances when value-added pharmaceutical industry has suffered because of duty on the import of raw materials while finished products have been allowed duty-free. Similarly, the country's electronics industry was decimated during the late 1980s and 1990s when the duty structure was reversed, making local manufacture unsustainable. Government procurement policies have also had deleterious consequences for industrial production and R&D on more than one occasion.

When a consistent set of enlightened policies have been applied, however, they have resulted in the desired results. A particularly successful example is the Engineering Development Board's effort to promote indigenisation in the automotive sector in the 1990s. Particularly noteworthy here are Toyota's supply chain development activities in the automotive sector and Honda's efforts to reduce costs and locally innovate in motorcycle production. EDB's work also led to considerable skill development and technology upgrading and created jobs in the economy. Today, the local subsidiaries of the three large Japanese automakers produce between 60-80% of the cars within the country.[186] Examples of such policy consistency and focus, however, have been few and far between.

4.3.3 Access to capital

The provision of government funds to businesses has varied over the years and across sectors. Large scale industry has benefitted from favourable policies (with the exception of nationalisation in the 1970s). The provision of funds for small and medium enterprises (SMEs) and new entrepreneurial ventures (NEVs) has not been adequate.

The playing field between large and well established business groups and smaller entrepreneurs has further skewed due to the banking sector's culture of requiring physical collateral for lending. Access to equity markets through the stock exchanges has been limited due to erratic performance of the latter. There is little or no access to venture capital within the country. Although a couple of large business houses have experimented with early stage venture capital, neither of these initiatives is seen as an unqualified success story. Plans for a public sector venture fund and a technology angels network have so far failed to materialise. By and large, Pakistan's capital market has failed to become a viable source of funds for new enterprises thus stunting the growth of a major source of innovation across the business spectrum.

4.3.4 Scientific and technical support to industry

4.3.4.1 Pakistan Council for Scientific and Industrial Research

PCSIR was created in the 1950s to promote partnerships between public sector R&D organisations and industry. Specific units were created within PCSIR to provide scientific and technical support to certain industries, such as pharmaceuticals, chemicals, food, and metallurgy. One particular success story was PCSIR's collaboration with Qarshi Industries. PCSIR played a formative role in the development of Johar Joshanda, a herbal cough and flu remedy widely acknowledged as one of the 25 most important innovations from Asia, and Jam-e-Shirin, a refreshing herbal drink. Inspired partly by its interaction with PCSIR, Qarshi Industries started an R&D Cell in 1981 that was later upgraded into a fully fledged laboratory. Qarshi Research International Ltd is today the only internationally accredited private sector laboratory in Pakistan.[187]

Despite these individual exceptions, PSCIR today only makes a small income from its commercial operations other than its role as a contract testing facility for companies that cannot afford their own testing equipment.[188] It has become the de-facto testing facility for the industry. Although useful, this diminishes the potential of PCSIR's human resources and technology infrastructure. PCSIR has been hamstrung by the inflexibility of its organisational structure and its inability to attract and reward entrepreneurial scientists. Only recently has this begun to change, although structural and organisational challenges remain.

A recent initiative to establish Business Technology Incubators by setting up pilot demonstration and handover plants could make PCSIR more relevant to the industry. Suitable incentive systems and reward mechanisms need to be put in place to make such ideas practically sustainable beyond the initial phase.

Other entities, such as the Pakistan Scientific and Technological Information Centre and Technology Commercialisation Corporation of Pakistan have had even less impact. Many of these initiatives have been marred by a lack of flexibility and inadequate incentives within public sector to deliver commercial returns. Should recent initiatives, including Pakistan Agriculture Technology Co. (PATCO), Common Facility Centres (CFCs), and SMEDA's Industry

Development Companies, such as Pakistan Gem and Jewellery Development Company, provide the necessary flexibility and incentives, they may be steps in the right direction for promoting industry development and industry-science collaborations. It is, however, too early to assess their full impact.

4.3.4.2 Pakistan Science Foundation

PSCIR is not the only public sector R&D organisation to have sought to engage industry. In 2003, Dr Farid Malik became the Chairman of the Pakistan Science Foundation (PSF), a government body to support science styled on the US National Science Foundation. Having previously worked in the United States for Intel, Malik brought his industry ethic of value-for-customer to PSF and quickly initiated a review of the effectiveness of PSF's funding activities. He redefined the selection criteria of its funding programmes to include clearly defined objectives, economic utility, and an industrial partner. Over 45 projects were initiated during Malik's tenure, including re-design and optimisation of a locally produced bicycle for cost-reduction; development of fibre glass reinforced compressed natural gas tanks; pilot plant for local production of green tea; and carrying out the integrity testing of gas pipelines for Sui Northern Gas Pakistan Ltd.

Other organisations, such as the National ICT R&D Fund, Pakistan Agriculture Technology Company and STEDEC have been created to promote collaborative partnerships between academic and research community, governments, and industry and derive socio-economic value from investments in S&T and these have done so with varying degrees of success.

4.5 Nurturing an entrepreneurial culture

4.5.1 ICT leads the way

The ICT industry has been a relative success story for Pakistan over the last decade. Today, it accounts for a major portion (over 80%) of the country's high technology exports. Starting from its early days of low-end coding and outsourcing work, this sector has matured into the more innovative and high-end activity. However, a lack of suitable government support has been a major bottleneck hindering the growth of this sector.[189]

Inspired by Silicon Valley and fuelled by returning expats (and their organisational platforms and social networks), a nascent entrepreneurial culture is emerging in Pakistan's ICT industry. Entrepreneurs with requisite skills, drive, and willingness to take risks and establish new ventures are beginning to reap substantial rewards. As ICT spreads through other sectors, so, too, could its entrepreneurial culture, thereby helping to promote innovation in Pakistan more widely. Pakistan Software Houses Association of IT and IT-enabled Services Companies (P@SHA) is one of the pioneering spirits behind these developments. Despite limited resources, P@SHA has organised "Start Up Insiders" mentoring workshops; a set of LaunchPad events that allow individuals to pitch new ideas in front of experienced judges from the industry; and an Annual ICT Awards Programme for Pakistani IT companies. Through these activities, P@SHA has led a regular stream of Pakistani entrepreneurs being recognised at prestigious international fora. Expatriate groups have also been important pioneers. For example, MIT's Enterprise Forum - Pakistan has collaborated with the Organisation of Pakistan Entrepreneurs of North America (OPEN) to run a Business Acceleration Programme for the last four years. P@SHA could benefit better if it had recourse to dedicated innovation funding to support its programmatic activities (see section 1.4.3).

Text Box 4-2: Opportunities for greater private sector participation in defence and strategic industries

The defence and strategic industries have traditionally been within the exclusive purview of the public sector and almost off-limits to private sector participation. In most developed, and many developing, countries such as USA and UK, private sector participation in defence research has generated considerable innovation and private (and public) return on investments. This has been a major weakness of Pakistan's defence establishment and a missed opportunity for the nation.

While there has been some history of commercializing dual-use technologies from other public sector entities – such as the Pakistan Atomic Energy Commission – into the defence sector, in recent years, there has been a greater opening up of defence to civilian suppliers and a move towards exploiting defence related R&D for commercial and civilian uses but this has been a slow transition. In the 1990s and 2000s, PAEC's Laser Group under the leadership of Dr. Shaukat Hameed Khan successfully commercialised a number of laser-based technologies such as Laser Range Finders (LRF) to the armed forces. In more recent years, a few private sector companies have emerged in this domain. Drs. Shoab Khan and Farrukh Kamran began working in Islamabad for Enabling Technologies, an R&D arm of a US based company, developing high speed multi-channel Voice Over IP (VOIP) chips. A breakaway from ET by a critical mass of PhDs led to the creation of the Centre for Advanced Research in Engineering (CARE) Pvt. Ltd. Now CEO, Dr Khan and his company have never looked back. CARE has developed cutting-edge communications and navigational equipment for Pakistan's strategic arsenal. Bravo Zulu International has designed and built aircraft simulators for a fraction of the cost for which they are available from abroad, and exported these simulators to Saudi Arabia and Egypt. Integrated Dynamics and SATUMA has produced unmanned aerial vehicles that have been used by the Air Force, and exported to Australia, Sri Lanka and Oman, among other countries.

Pakistan could benefit immensely from spin-on and spin-off of its defence and strategic capability by promoting private sector participation in these industries, and encouraging public sector entities to be more commercially and export orientated. One particular obstacle to innovation in this sector is the lack of continuity at senior management levels within defence organisations. This could be alleviated through the creation of permanent R&D entities, such as a National Engineering and Scientific Commission (NESCOM), with dedicated staff and an appropriate incentives and promotion structure to support long-term innovation.

4.5.2 Incubators, angel networks, and venture capital

The culture of incubation, angel networks, and venture capital is relatively nascent in Pakistan. One of the earliest and most notable examples is TMT Ventures created in the early 2000s by a local brokerage house. While unable to deliver the returns expected of it, TMT Ventures has not been an outright failure. It is important for Pakistan's entrepreneurial culture and investment communities to learn from these experiences to create better organisational models in the future.

Incubators have recently begun to pop up across universities and other places. One of the oldest of these incubators, the Technology Incubation Centre, has been operating at NUST since 2004 but is yet to deliver a true commercial success story. Created by serial entrepreneur and Chairman of Punjab Information Board (PITB) is Plan9 – a technology incubator based out of Lahore – that is the 3rd year of its existence and has done fairly well on several counts. To date, the Centre has spawned tens of companies and some have received international visibility and, to a lesser extent, some investment funding as well.[194]

New initiatives have recently been launched to establish business incubators at leading public sector universities. An agribusiness incubator at University of Agriculture at Faisalabad (UAF) has been launched with the support of USAID's Competitiveness Support Fund. In 2010, this incubator boasted 18 incubatees.[195]

A Technology Angels Network backed by MIT Enterprise Forum Pakistan has been announced for over an year now but has been unable to gain the necessary traction to close the associated fund. The fund suffers from a critical design flaw, namely, the difficulties in balancing multiple conflicting interests of investors from both inside and outside Pakistan through funds incorporated in USA with a mandate to invest in Pakistan. The small size of the fund coupled with lack of geographical proximity between investors and the investment and the resultant loss of control may explain its inability to convince investors so far.

In recent years, there has been somewhat of a boonm in the entrepreneurial and innovation eco-system of Pakistan. A year ago, P@SHA, in collaboration with Google for Entrepreneurs, Samsung, and the US Department of State launched its own incubator - The NEST i/o with the promised funding of $1.7 million over 3 years. Samsung announced that this will be the first of several that they wish to launch in Pakistan. Off the bat, The NEST i/o has demonstrated some success in getting its incubatees funded by local angels and venture investors.

There have been several privately funded efforts as well. Peshawar 2.0 - a new entrant in the game has launched Basecamp - a co-working space and resently announced Revolt - a 4-month incubation programme. Lahore University of Management Sciences established Lahore Centre for Entrepreneurship - an incubator to cater to audiences both inside and outside LUMS. DotZero is another privately funded incubation space in Karachi which has also launched DotZero Ventures, Pakistan's newest venture capital fund. Jamal Khan, of ARPA Ventures is also pushing forward with an interesting model of early stage acquisitions particularly in the ecommerce space.

Textbox 4-4: ICT leads the way in entrepreneurship and innovation

Dr. Arshad Ali is the founding Principal of the School of Electrical Engineering and Computer Sciences (SEECS) at the National University of Sciences and Technology which is one of the leading universities carrying out research in information technology and computer science. SEECS' particular distinctiveness is in its ability to engage industry in academic research. It has experimented with the idea of plug and play R&D Labs and has convinced a number of industry giants, such as NCR, IBM, CISCO and Huawei to set up labs at SEECS. In the process, SEECS' research portfolio and faculty has grown and prospered considerably, many of whom have delved into start-ups as well. Research areas include distributed and grid computing, networks, high performance computing, IP technologies, Symantec web, and information security.

Until quite recently, Dr Sarmad Hussain headed NUCES' Centre for Research in Urdu Language Processing (CRULP). He had an ambitious agenda to develop local language computing and make the web and other new media technologies accessible to a vast majority of non-English speaking population. CRULP is part of an Asia-wide PanL10n Project funded by IDRC of Canada, comprising 10 country partners and over 10+ linguists, engineers, computer and social scientists joined together to create an infrastructure and capability for local language processing in Asian developing countries. Husain's work ranges from linguistic research, to standards development, and from basic localisation such as development of tools for browsing and document processing, to advanced linguistic computing.[190]

COMSATS Institute of Information Technology (CIIT) – a centre of excellence of the Commission on Science and Technology for Sustainable Development in the South (COMSATS) – is another rising star on Pakistan's IT scene and has been a beneficiary of considerable federal funding in recent years. Of particular note, is CIIT's bio-informatics and e-health research that combines a multidisciplinary set of fields from IT, Management, Telecommunication and data processing. CIIT and the University of Otago, New Zealand jointly publish A Journal of Health Informatics in Developing Countries.[191] CIIT is well connected with a number of international bodies, such as the World Health Organisation and several national regulators.[192]

Netsol is one of the leading players in the industry. It has an automotive leasing product that has a significant presence in Eastern Europe and Asia Pacific region and a dominant position in the Chinese market. Mixit, another leading player, has developed software that connects directly with over 70 liquidity venues and 200 algorithmic destinations including the New York Stock Exchange and is used by a vast majority of brokerage firms in the US. Mixit was recently acquired by a British company for £17.6 million thus creating the biggest and most visible "exit" for a Pakistani IT company to date.[193]

Sofizar has grown at a rapid pace to become one of the top-ten companies, globally, in its search engine optimisation segment worldwide. It grew from zero to more than $15 million-plus revenues in just over 5 years. A Pakistani company, GameView Studios, was acquired by Japanese gaming giant DeNA and now has several hundred 400+ people working in its gaming studio in Lahore. TinTash. GeniTeam, and TkXeL have produced a number of top-10 best selling games on the Apple iStore and Mindstorm Studios became the first Pakistani company to publish a complete fully-functional multi-player game called the Cricket Revolution.

Beyond these commercial success stories, the important work at NADRA, Telenor Easy Paisa, and LUMS-SUPARCO GIS Village Mapping Project demonstrate considerable promise and many of these areas could be developed further.

Kalsoom Lakhani's Invest to Innovate (i2i) is another private player that has established itself in the social innovation space with its innovator accelerator model and has delivered at least a few fundraising successes, most notably, Popinjay, Markhor, ProCheck, and Savaree. Acumen Fund, the NY-based social impact fund run by the charismatic Jacquiline Novogratz, has been active in Pakistan for several years now and has invested in a number BOP-focused impact ventures.

Another new entrant in the space is the Founder Institute - a Silicon Valley-based 'global' accerlator that is trying introduce rigorous curriculum along with mentoring as a means to 'graduate' founders. This , in particular, is aimed at the professional audience and operates weekly after-work sessions and extensive take home assignments to enable the participants to create a company within 4 months. Bouyed by these recent successes, there are a number of plans to set up pre-seed and seed funds to jumpstart the entrepreneurial eco-system of Pakistan. IT and technology startups will probably lead the way but other sectors of the economy may not be that far behind.

Pakistan Innovation Foundation (PIF) is a private-sector driven entity that seeks to create an innovation society in Pakistan primarily by getting the private sector on board and working towards the wealth creation from innovation but also working with donors and other entities to support innovation within the society. Over 2 years of its existence, PIF has launched a series of innovation challenges focused on manufacturing, agriculture, learning, and social innovation engaging thousands of participants across the country seeking to think creatively to solve problems. PIF also sees the tide of private sector interest in innovation lifting soon.

There is considerable optimism - 'almost a bubble' - in the air that the next 5 years will see a lot of activity in the entrepreneurial space and will see Pakistan reach the escape velocity to finally take off in a big way and reach to new heights.

4.5.3 The rise of entrepreneurial universities

A number of universities are becoming increasingly entrepreneurial and commercially orientated. LUMS was the first private sector business school in Pakistan. It has embarked on an experiment in elite engineering education by creating a new School of Sciences and Engineering. Professor Asad Abedi, the School's Founding Dean, has described it as '(perhaps) an MIT, Stanford, or Caltech of Pakistan.'[196] Despite some initial teething problems there are already interesting signs of innovation. A Rhodes Scholar with a PhD in physics, Dr Mohammed Sabieh Anwar has embarked upon a unique quest to create his own laboratory equipment for his three semester applied physics track at the School. Today, his research group is able to provide this equipment to other institutions in the country, thereby saving them precious foreign exchange.

NUECS, formerly BCCI FAST, was the first private-sector computer science university in Pakistan established through a donation by Agha Hasan Abedi of Bank of Credit and Commerce (BCCI) fame. FAST was instrumental in setting standards for computer science education in the country and its alumni are scattered around the globe, particularly in the Pakistani Diaspora in North America. BCCI FAST was the first university to begin organising National Software Competitions in early 1990s.

Created in 2006, the Punjwani Centre for Molecular Medicine and Drug Research (PCMD) at Karachi University's International Centre for Chemical and Biological Sciences (ICCBS) provides a multidisciplinary environment for 'academicians, clinicians and pharmaceutical researchers…to translate basic scientific discoveries into new therapies, vaccines and diagnostic tests.'[197] Dr Kaneez Fatima, a visiting faculty member, is adamant that PCMD needs to go beyond the rhetoric of 'training manpower' and must bring the fruits of its research to the market. PCMD will be an important test of how scientists from multiple disciplines can work together in and carry out commercially orientated research.

NUST has fully embraced the concept of being an entrepreneurial university. NUST has a fully functional Industrial Advisory Board and a consulting division. It has even created Pakistan's first incubator and first planned S&T Park. One of NUST's flagship schools at its newly constructed campus in Islamabad is the School of Electrical Engineering and Computer Sciences (SEECS). It was intentionally constructed next to the NUST Business School (NBS) to foster cross-disciplinary collaborations. Successes in such multidisciplinary collaborations have so far been somewhat limited.

These interactions have not been driven purely from the direction of academia. They have also been established by industry reaching out to universities the first instance. For example, DESCON Chemicals approached two academic researchers (Drs Fahim Qureshi and Adnan Ahmed) at the Chemistry Department at Government College University (GCU) to solve a problem concerning the low strength of one of their food packaging adhesives. The partners discovered that the arrangements to draw on the skills of the researchers were difficult. Nonetheless, this collaboration succeeded because of the researchers' prior experience of working in industry and that of DESCON's leadership with academia. Today, Mr Razzak Dawood, DESCON's CEO, and a former Commerce Minister and Rector of LUMS, is enthusiastic about DESCON's continued partnership with Government College University, and believes this could be a model for the country's other industrialists.

Text Box 4-5: Potential for Business Innovations within Agriculture

The country holds significant potential to revolutionize economic growth if necessary improvements are made in the agriculture supply chain. The agriculture sector can rightly claim numerous innovations such as doubling of crops during green revolution; the discovery of satellite gene to combat against the notorious Cotton Curl Leaf Virus; development of vaccine for foot and mouth disease; and Integrated Pest Management programme, to name a few. At the same time the future seems bright with multitude of innovations such as drip irrigation technology for enhancing water utilization; genetic marker panels that make it possible to conduct genetic selection of livestock; and spider venom based Hvt Cotton – a crop variety superior to Bollgard II (Bt Cotton) and its next generation Bollgard III that is under development.

Historically speaking, there has been high emphasis on inventing new crop varieties. However, in the future there is a need to bring about innovations in commercialization processes and farming practices so that commercial benefits of these inventions could be exploited to their full potential. The revolutionary economic growth would not be possible if agriculture supply chain is not established in an integrated and holistic manner.

Besides, while the country holds an extensive research and development capacity, the agriculture system as a whole faces some challenges that need to be addressed: (1) the crop variety development process is rather slow because of the involvement of various entities, lag in decision-making, and coordination issues, (2) the public sector infrastructure lacks business orientation as the market pressures of delivery speed, quality output, and/or cost are nonexistent, (3) duplication of efforts and inefficient use of resources, (4) there is limited capacity for commercializing and multiplying new seed varieties, especially genetically engineered or biotechnology based crop varieties, and (5) there has been limited focus on farming practices and management of the crops produced.

One promising development in this regard has been the formation of Pakistan Agriculture Council (PAC) – an umbrella body of leading agriculture and food companies in Pakistan – to help carry out capacity building (through a modern farmer school), research and advocacy. With so much clout behind this, PAC holds so much potential and promise.

5. Culture

Pakistan is a country of over 170 million people with more than half a dozen local languages and diverse regional cultures. Yet there is a common religio-cultural heritage that unifies the country. A vast majority, for instance, can understand and converse in the national language Urdu. Modern Urdu evolved over a period of 900 years as a mixture of words from over half a dozen languages such as Turkish, Arabic, Persian, as well as old languages of central Asia (or Reekhta or 'old Urdu) and Indian sub-continent (Sanskrit)[198] – and high school graduates possess a working knowledge of English. This makes Pakistan a unique cultural melting pot and offers opportunities to foster creativity and innovation by leveraging the collective resource of over 100 million adults.

For a country that is at the meeting place of three very different socio-cultural systems (namely, Indian, Iranian and the central Asian), influenced deeply by the tribal norms of Saudi Arabia because of religious affinity, and lived under colonial rule for nearly 200 years, Pakistan has done well to gradually evolve a national ethos. Many challenges still remain. There is still considerable tension between the two alternative narratives that emphasise Pakistan as an Islamic state or a state created for Muslims of the subcontinent but with equal rights for people of all religions. In such a dynamic two outcomes could possibly emerge; either the diversity becomes the crucible for creativity and innovation or the tendency to dominate over other perspectives makes the people rigid and dogmatic. Unlike Iran, though, Pakistan of today shows signs of both these dynamics at play. The debate is never-ending.

Professor Pervez Hoodbhoy believes Pakistan has failed to develop a true scientific culture that encourages critical thinking and rational inquiry. While acknowledging Pakistan's limited successes in applied sciences and engineering,[199] in particular, agricultural research and defence and nuclear engineering, he laments the state of basic science in Pakistan.[200] According to Hoodbhoy, 'science hardly exists' in Pakistan.[201] 'Why are there only a dozen or two internationally known Pakistani inventors, scientists, writers, etc for a nation of 165 million people?' he asks.[202]

This question provokes a very different response from another illustrious MIT alumnus. Professor Adil Najam, the Vice Chancellor of Lahore University of Management Sciences (LUMS), and formerly the Director of the Pardee Centre for the Study of Global Long Range Future at Boston University, strikes a more positive, albeit still critical, note. Adil believes that Pakistan has done relatively well and punched far above its weight for a nation of its socio-economic standing and geopolitical circumstances. 'Look at it this way', he says, 'for a country whose human development indicators compare with Sub-Saharan Africa, science has done quite well in Pakistan'. Adil believes that it is unfair to view Pakistan's success from the lens of a western audience or an expatriate who has lived, studied, and worked abroad for a long time.[203] The truth may lie somewhere between Hoodbhoy's idealism and Adil's pragmatism.

This chapter looks at the role of religion, history, gender and public attitudes in Pakistan towards knowledge, in general, and science, in particular.

5.1 Defining Pakistan's identity

5.1.1 Religion, politics, and history

Religion is a pervasive force in Pakistan, the roots of which roots go back to the story of the creation of Pakistan itself. Pakistan came into existence on August 14, 1947 as the homeland of Muslims of the Indian sub-continent a result of a freedom movement against the British Raj in India that has been defined, in large part, in religious terms.

Interestingly though, Pakistan's founder Mohammed Ali Jinnah – a modern secular lawyer whose portrait hangs at the entrance of Lincoln's Inn in London – wanted Pakistan to be fashioned in the manner of a modern constitutional state where rights of all minorities will be secure.[204] The debate over whether Pakistan was to be, and is, an Islamic state or a state for Muslims, remains ongoing without a clear resolution in sight. Today, more than 95% of Pakistan's population is Muslim, predominantly Sunni (80%) rather than Shia (20%). There is a small minority of Hindus, Christians, and other religious groups.[205]

The religious outlook of Pakistanis is determined probably as much by Islam as it is by the local culture and politics. Often the two are intertwined and confused. The debate about whether this religious outlook helps or hinders scientific progress is a perennial and sensitive one in Pakistan, a country not known for its tolerance to alternative worldviews on contentious topics.[206] Within Pakistan, as in most of Muslim countries, there is a spectrum of viewpoints on the place of scientific learning.[207] Most Pakistani researchers and scientists would maintain the view that the acquisition of knowledge and scientific pursuit in general is not in disaccord with Islamic thought and religious belief but in fact strongly supports it. This is amply reflected in the glorious contributions of Muslim scientists and philosophers of another age such as Ibn-e-Sina (Avicenna), Ibn-Haytham (Alhazen), Al-Razi (Razes), Al-Khwarzimi, Ibn-e-Rushd (Averroes), etc. and these views have been espoused by Muslim reformers and thinkers like Sayed Jamal-uddin Al-Afghani,[208] Sir Syed Ahmed Khan,[209] Sayyed Hossein Nasr, and Osman Bakar,[210] among others.

In more recent times, though, there has been a steady growth in a minority that holds a conservative, rather narrow, and increasingly extreme interpretation of Islam.[211] This view is more mistrustful of science, modernity, or critical enquiry. While the vast majority of Pakistan remains moderate, the power of this alternate narrative has grown over the years for a number of geopolitical reasons. Pakistan's history of military rule and the resulting lessening of intellectual space for dialogue and discourse within the society coupled with tendency towards dogmatic thinking that discourages true scientific mindsets of experimentation and enquiry has a role to play as has the growing extremism in the society in in the current geopolitical turmoil of the world,. This, however, also creates the need and opportunity for a vigorous debate within the society. This debate has not yet taken place in Pakistan with the right kind of seriousness that it deserves.

Pakistan has produced very few scholars prepared to seriously engage with it. Those who have, such as the British writer of Pakistani origin Ziauddin Sardar,[212] who has been named one of UK's leading Muslim intellectuals, and Muzzaffar Iqbal,[213] an émigré to Canada, have chosen to do so from outside rather than inside Pakistan. One exception is Professor Pervez Hoodbhoy who has maintained that certain religious attitudes and philosophical ideologies hinder true scientific learning.[214] Hoodbhoy believes, among other things, that the current mode of Islamic education has influenced an educational pedagogy responsible, to a large extent, for perpetuating rote learning and a lack of critical inquiry and imagination among young people in Pakistan.

Historical factors may also be important. Ziauddin Sardar stresses that colonial powers developed an economic and intellectual dependency, including scientific and technological dependency, that deprived their colonies of the incentives and institutions to innovate.[215] Dr Sohaib Khan, the Chair of Computer Science Department at LUMS, is also critical of the ill effects of colonialism on Pakistan's STI that he believes continue to last till this day. According to Sohaib, STI cannot develop until Pakistan sheds this intellectual slavery and develops self-belief.[216]

5.1.2 Pakistan's image on the global stage

Pakistan's geostrategic location, coupled with its proximity to an emerging rivalry between India and China, has been both a blessing and a challenge. [OIC-265] For acts of commission and omission, Pakistan has found itself embroiled in an internecine Great Game in the corridors of Central Asia in the 1980s and again at the centre for the Global War on Terrorism in the early-2000s. Forced to take a side on the eve of 9/11, Pakistan's political leadership put their support behind the US led coalition and have since found themselves in the cross-hairs of a conflict that has sapped the energies and stretched the country's resources to its limits.

The menace of global terrorism and the country's security challenge has come to define Pakistan's image abroad and become the battle of its own survival at home. However, life for a vast majority of Pakistanis remains very much normal. The western media's single-minded focus on the security problems afflicting Pakistan has overshadowed almost everything else that the country has to offer. The resultant securitisation of Pakistan's international image has also erected often insurmountable obstacles and challenges for institutions seeking to participate in the global scientific enterprise and the knowledge economy.

5.1.3 Gender

In Benazir Bhutto, Pakistan was among the very first Islamic World countries to have a female head of government. Women have been active in Pakistan's social and political life right from the days of the freedom movement when Fatima Jinnah, Begum Ra'na Liaquat Ali Khan, Lady Viqar-un-Nisa Noon, and Lady Hidayatullah, among others. Currently, significant government positions such as Speaker of National Assembly, Foreign Minister, and the Ambassador the United States, are held by women. A policy of positive action is also promoted to ensure that there are specific seats for women in the Pakistani parliament. In light of such promising signs of political equity, women have increasingly found themselves in positions of influence. Today, women in Pakistan have broken significant barriers, such as training alongside men in the defence academies, flying combat missions on fighter aircrafts, and sporting a national cricket team that won the Asia Cup in 2010.

Despite this progress serious gaps remain. The female labour force participation rate remains quite low at around 22% (up from 9% in 1971-72 but compared to 82% for men).[217] This compares with 23.8% for Egypt, 24.8% for Lebanon, 31.8% for Iran, 49.8% for Indonesia, and 57.2% for Bangladesh.[218] The majority of these women, as much as 74%, work in agriculture, mainly on livestock. A significant proportion of women work in subsistence activities, as well as unpaid family work, restricting their ability to transform employment into social and economic empowerment.[219]

The 2005 Educational Census noted that a total of 838,000 women were enrolled in higher education, comprising 41% of medical degrees, 73% of nursing degrees, 75% of education degrees; but only 15% of business and accounting degrees, 15% of engineering degrees.[220] A Labour Force Survey also revealed that in 2007-8 only 7.4% of women were entrepreneurs.[221]

The Women At Work report by the Social Policy Development Centre (SPDC) noted incidences of sexual harassment, work place discrimination, onerous labour laws, and diminished access to opportunities, such as micro-credit.[222] Noticeably absent from the report was women's participation in the scientific professions.

5.2 Popularising science

In Pakistan, science is not particularly well known for its contributions to socio-economic development which are hardly publicised in Pakistan. Scientists' accomplishments are not well known and they are not popular role models for the younger generation. Science is not a profession of first choice for young Pakistani men and women. The scientific profession does not attract the best and brightest within the country. There is a clear need to present science as a worthwhile activity and an exciting career and some efforts have been carried out in this respect.

In 1994, the Science Education Group developed a popular documentary series titled Bazm-e-Kainat ("The Universal Colloqium") that was deemed successful in stimulating public interest in science.[223] However, this is a notable exception to the deficiencies in the media's portrayal of science and scientific careers despite the recent liberalisation of electronic media in Pakistan. The print media's coverage of science is quite weak with a limited number of specialist general interest scientific publications in English, Urdu or vernacular languages.

New social spaces are starting to emerge to improve public debate about science. The Second Floor (T2F) is perhaps the closest to the cultural and intellectual spaces of yesteryears. A brain child of Sabeen Mahmud, a social activist and lover of art and culture who was unfortunately assassinated in April 2015 for the precise crime of creating the space for dialogue, T2F provides a unique and inclusive environment for creative expression that brings together Karachi's young and old in a melange of ideas from science, technology, literature, culture and art. One of T2F's signature initiatives is a lecture series called Science Ka Adda (or House of Science) designed as a platform for debate and discussion about science and how it impacts everyday lives. While T2F is native to Pakistan, another similar idea born outside of the country has taken root. Technology, Entertainment, and Design (TED) is a non-profit organisation devoted to disseminating 'ideas worth spreading' by bringing together creative and visionary people for events and conferences.[224] TED has found a ready reception in Pakistan, and a number of TEDx events have initiated debates about social and technological issues.

What T2F and TED are doing in the real world, others are trying to achieve virtually in the blogosphere. The Science Technology and Education Policy blog provides a virtual space to engage concerned citizens in a discourse on science and education policy. It recently won the "Best Education Blog Award" at the first National Blog Awards of Pakistan.[225] Other similar initiatives include PakWired, ProPakistani, TechJuice, and Green and White - all focused on disseminating inspiring stories about the ICT sector.

5.3 Building capacity for public engagement

If popularising science is one part of the challenge, proactive public engagement by the scientific community with wider society is the other. By and large, the tradition of public engagement is quite weak within the scientific community of Pakistan. The capacity of Pakistani scientists to engage with public discourse on important social and philosophical issues of relevance to society is limited. This is partly due to the relatively narrow disciplinary training of scientists and engineers, in general, and the professions, in particular. Pakistan's education system forces pupils to choose a discipline (whether engineering, medicine, commerce, arts, or humanities) at a very early stage and deprives them of a broad-based curriculum or a liberal arts education, as well as a good foundation in disciplines, such as communication skills and philosophy of science.

5.3.1 Changing norms of public engagement

Aga Khan University (AKU) and Hospital (see textbox 2-2) is perhaps a decade ahead of other institutions in Pakistan in respect of public engagement and has been a trend setter for other institutions to follow.[226] Through its College of Community Health Sciences, it was the first medical school to introduce the idea that universities must not just be ivory towers but should work within the communities. 'For us, the big idea,' says Dr El Nasser Lalani, AKU's Dean of Research, 'is to understand the socioeconomic determinants of health. Globally, the healthcare agenda is moving towards the importance of prevention. There is a gradual shift to invest in the causes- often socioeconomic- rather than symptoms of diseases. This is where AKU is making, and hopes to make, a significant contribution to the global healthcare debate."[227]

AKU also introduced standards for nursing education in Pakistan and forced the development of national standards. Seeking to create more holistic medical professionals able to engage with their communities, it is the first medical university to consider introducing liberal arts education in medical curriculum in Pakistan.

5.3.2 The need for a social contract

Pakistan lacks a social contract between the scientific community and wider society that is the hallmark of advanced Western societies, and has been carefully nurtured over decades, if not centuries. A national dialogue could help to put the building blocks in place by allowing Pakistan's scientific community to make the case for public support of science and demonstrate the benefits of creating new knowledge by applying it to improve the country's material wellbeing and economic prosperity. Only once a national consensus on the proper and due role of science in the society has been developed could the public support for science be guaranteed.

Gaining this wider grassroots support would help STI to become a political priority at the highest levels of decision making and be better appreciated within the corridors of economic power.

5.3.3 Societal attitudes towards climate change

In October 2008, the Planning Commission set up a Task Force on Climate Change. This was perhaps one of the first serious attempts by the Government to tackle climate change issues systematically (see section 6.3). Although comprehensive with concrete recommendations, the publication of the Task Force's report has failed to create a wider debate within society about the seriousness of climate change. Without a robust debate and sense of urgency, it may be unlikely to lead to substantive policy changes.

The general public consensus within Pakistan seems to be that climate change is something happening from outside (global and regional forces) rather than inside (through individual actions). This could partly reflect Pakistan's relatively minor status as a greenhouse gases emitter. Pakistan only produces approximately 0.8% of total emissions, ranking only as 135th of global greenhouse gas emitters.[228] Even though Pakistan's own emissions are relatively low, the global nature of the problem does not leave Pakistan immune to the effects of climate change. Temperatures over Pakistan rose by 0.6°C over the last century, which is broadly in line with global trends. Precipitation has increased 25%.[229] The recession of glaciers in the north and the rapid erosion of coastal communities in the south are of particular concern.

5.4 Neglect of the Social Sciences

While hard sciences and technology has received more attention in recent years, the social sciences and humanities have lagged behind. In fact, one particular observer has argued that there has been a complete lack of policy towards the social sciences in Pakistan.[230]

Writing in 1989, Dr. S. H. Hashmi, a former Vice Chancellor of Quaid-e-Azam University noted that "Social Sciences have remained grossly under- developed and the number of social scientists miserably low and declining. Social Sciences, on the whole, have been badly ignored."[231] A national conference co-hosted by the University Grants Commission (UGC) in 1988 to discuss the state of social sciences and the causational factors of their under-development in Pakistan made several recommendations including, among others, the creation of a National Social Sciences Research Council and a scholarship programme to enhance the "alarmingly low number of social scientists in the country."[232] The Conference expressed a desire to strengthen and organise social sciences along rigorous scientific methodologies patterned after natural and physical sciences.[233]

However, these good intentions aside, not much had changed qualitatively over a decade later as S. Akbar Zaidi – a noted economist – wrote a scathing review of the "dismal state" social sciences in the country.[234] With the exception of economics, local journal publishing in Pakistan is almost non-existent. Zaidi found that only three of the twenty-two journals – representing a vast majority of the universe of journals published in the country – were peer reviewed.[235] The state's neglect of the social sciences has meant that no strong, rational social science tradition could be established.[236]

Yet the social sciences are critical to Pakistan's future development. 'A large number of Pakistan's most pressing problems', says Dr Ishrat Hussein, an ex-Governor of State Bank of Pakistan and the Chair of HEC's Social Sciences Committee, 'are of a social character and amenable to interventions and contributions by social scientists'.[237] After an initial period of neglect where the focus was on 'hard sciences', the social sciences have begun to receive some attention from the Higher Education Commission (HEC).[238] A Social Sciences and Humanities Research Council has been established. Foreign scholarships have been awarded and an attempt to revive the quality of local journals has been made. However, these efforts are yet to bear results. The social sciences are the only areas that have registered a decline in relative impact during the recent years of investment in higher education under the HEC.[239]

The neglect of the social sciences (and humanities) represents a deep problem about the type of society that Pakistan wants to become. A technologically advanced country cannot be created in vacuum. A society cannot produce great scientists and innovators without creating great philosophers, social scientists, historians and artists. Without exposure to this broader set of knowledge, it would be difficult for Pakistan to be instilled with fundamental virtues that also serve as necessary conditions for science: intellectual freedom, critical inquiry and open debate.

5.4.2 Science policy and innovation studies

There is a general dearth of capability and competence within Pakistan to carry out systematic and rigorous science policy analysis and research. A 2007 USAID report assessing higher education reforms singled out a lack of capacity to carry out 'quantitative science policy' analysis and evaluation as a critical weakness in the country's ability to set up and evaluate effective science and research infrastructure.[240] With a couple of exceptions, there are hardly any think tanks of good enough quality and independence to consider the country's problems and advise on their solutions. Universities do not provide enough leadership on issues of national importance.

Another noticeable absence within the social sciences realm is that of the discipline of innovation studies. With the exception of one particular centre – the Mehran University's Institute of Science, Technology, and Development (MUISTD) – there is hardly any capability of note within the country study innovation in a systematic way. Yet formally understanding the changing nature of innovation – at the micro, macro, and multidisciplinary levels – is critical to the practice of public policy to support new growth opportunities and must, therefore, be a priority for policy-makers.[241]

5.5 Ethics of science

5.5.1 Establishing systems of ethics

In the recent years, with HEC's efforts, a high level of awareness has been created about maintaining high standards of ethics in conducting scientific research work and the need to safe guard against plagiarism. Universities now have access to software to detect cases of plagiarism in academic work of various types.

However, there have been a number of fairly high profile cases (and allegations) of plagiarism. Dr. Shaukat Hameed Khan, the Coordinator General of Comstech and former Executive Director of Society for the Advancement of Engineering, Sciences, and Technology in Pakistan (SOPREST) and the former Vice Chancellor of Ghulam Ishaq Khan Institute (GIKI) believes is the blowback from the 'publish and get paid' policies that needs a re-evaluation. While HEC has come down hard on offenders, Khan believes that there needs to be a mechanism to prevent such instances in the first place which could happen by adopting a more stringent policy regime but also ensuring the right balance of incentives within the system.

5.5.2 Carrying out research responsibly

Many universities have also formulated their own policies regarding use of animals in laboratory experiments and national level guidelines have also been developed for research in the biotechnology and genetic engineering areas. Pakistan has a fairly well-functioning regulatory and legal framework to oversee the introduction of genetically modified crops. Biosafety trials are quite rigorous and care is exercised to ensure that new varieties of crops are properly inspected before commercialisation. A major obstacle to progress in biotechnology and genetic engineering is the lack of institutional capability to carry out biosafety trials. 'What would be most useful contribution on the part of potential donors', says Dr. Mansoor, Head of Department of Agricultural Biotechnology at NIBGE, 'is to help us develop indigenous capability to carry out biosafety trials so that commercialisation can keep pace with progress in the labs'. Developing a rigorous biosafety capability would further strengthen norms and ethics of research in Pakistan.

5.5.3 Academic freedoms

Although faculty at public sector universities enjoy life-long employment as government servants, their ability to speak their mind has traditionally been limited by a host of factors, such as recriminations and social isolation. Education International's EI Barometer ranks Pakistan as a Category 3 (Freedom Restricted) country noting, among other things, 'student violence and intolerance, through groups linked with political parties.'[242] The introduction of academic tenure within universities and stronger faculty involvement in university governance structures is expected to gradually improve the situation..

Text Box 5-1: Culture and Agricultural Science and Innovation

Agriculture sector in Pakistan has a strong scientific culture which has been realized as a result of government funding in the forms of establishing research and development centres , the inflow of researchers produced through effective higher education institutions available in the country, and the market needs of new developments – pest resistance; shortening crop growing times; weather, soil and water issues; and area specific new crops are such facts that require continuous stream of developments. At the same time the research community has been open to embracing new technological developments happening in the world – the use of biotechnology in Pakistan since early 1980s. This would have not been possible in the absence of a scientific culture and approach employed within the community associated with research and development.

The percentage of female involved in scientific developments in agriculture sector has been 27% which is quite promising given the fact that the female literacy rate hovers around 60% of male in the country . Women are working shoulder by shoulder with men in this sector not only in research and development but also in the farm fields – a fact well known in Pakistan.

The interest in agriculture development is widespread within the country that ranges from agriculture scientific community, through farmers themselves, educationalists, journalists, businessmen, to policy makers. Much effort in the past has been laid on R&D for new crop varieties. At the same time the country has established a strong bio-safety clearance process for new variety developments. Generally speaking there has been a culture of coming up with new things rather than creating economic impact through those things. However, in recent times a significant need is being felt to exploit the potential of management and social sciences in order to improve commercialization and yield improvement.

6. Sustainability

In August 2010, Pakistan's fragile natural environment was back on the front pages. It had been there before when a major earthquake decimated the country's North Western Frontier Province in 2005. Dubbed as Pakistan's 'Katrina' [243] and 'Tsunami from the sky,' [244] this new disaster was even more widespread and destructive. According to the World Bank, the total cost of the floods is in the order of $10 billion.[245] With a crippling effect on Pakistan's agriculture and livestock and damage to its infrastructure, the effect of the floods is likely to be felt for many years.

Dr Ishfaque Ahmed is the founder of the Global Climate Impacts Study Centre (GCISC), Pakistan's first institution for systematically assessing the impact of climate change. He is confident that there is a link between the flash floods of 2010 and global climate change. Dr Ahmed notes that there are growing fears it may not be a once-in-80-years event. A number of climate change scientists in the country's northern regions claim that 'such extreme events may not remain rare but become frequent'.[246] While GCISC is a welcome step in the right direction, the tradition of climate science is relatively new in Pakistan and needs considerable strengthening. Not enough universities engage in climate research in a systematic way and whatever capability exists is scattered. There is not yet an effective champion for climate science in the country.

Sustainability is one of the greatest challenges facing Pakistan, and this chapter looks at how this creates an opportunity and urgency for STI in this area, and how it might be prioritised and further developed in Pakistan.

6.1 Addressing the energy crisis

Pakistan lies at the intersection of two strategically located gateways. Its port cities of Karachi and Gawadar form an important mid-point on the trade route between the East and the West. Like 'a sword cut through the mountains', the Khyber Pass opens the historical trade route from the southern seas to China, Central Asia, and Russia in the North. The Khyber Pass has been crossed by many conquerors throughout history from Darius I to Alexander the Great and Genghis Khan to Tamerlane. Although a very busy trade route in the past, in recent years prospects of a series of natural pipelines has made this region a serious contender for being a future energy corridor.

The present day realities of Pakistan's energy situation are much less exciting. Pakistan has a total of 19,500 MW installed power capacity. Two-thirds are provided by fossil fuels (mainly oil) and one third by water (hydropower plants). A small proportion is generated by nuclear power (about 2%).[247] Unpredictable spikes in oil prices over the last few years have threatened the country's capability to provide sufficient electricity to meet its development needs. The shortage of up to 5000 MW has been overcome through increases in the price of electricity and rolling black outs. Power shortages have darkened Pakistan's glittering cities for up to 12 hours a day, entailing adverse economic and social impacts across industrial sectors and on Pakistanis' daily lives throughout the country. S&T will be central to diversifying electricity generation away from expensive foreign oil imports and better exploiting domestically available resources, such as coal and hydropower, and moving towards cleaner fuels.

6.1.1 Leveraging one of the world's largest coal reserves

According to Dr Samar Mubarakmand, a former senior figure in Pakistan's nuclear programme and Member (Science and Technology) of the Planning Commission, 'the energy crisis in the country is the single most important technical problem that needs to be solved. If our industry and businesses can have access to cheap energy, we could become as competitive as India and China,' claims Mubarakmand. 'Without energy we would be relegated to the stone ages,' he adds.[248]

At approximately1.4 Billion BTU, Pakistan sits on one of the world's largest coals reserves- capable of delivering more energy than the oil reserves in Saudi Arabia and Iran combined.[249] One problem is how to mine the coal in the presence of aquifers sitting above coal deposits through either in-situ gasification or other innovative methods. Another concerns the significant technical, operational, logistic and funding challenges to exploiting these reserves in an environmentally friendly way.

Mubarakmand's approach is to use industrial scale, in-situ gasification of coal – a feat that has never been demonstrated at this scale in the world before. Gasified coal can then be used either as combustable gas or, through Fischer – Tropsch process, converted into gasoline and diesel. In-situ gasification is more environmentally friendly as compared to traditional coal mining and gasification. 'We have looked at all the relevant literature in the area, including smaller scale in-situ plants operating in South Africa and elsewhere, and are done with the design of the chemical infrastructure and the plants ... The mining necessary to put in place the infrastructure- pipe and burners- to gasify coal underground is going to start shortly'. Mubarakmand believes his approach could start producing electricity by mid-2012.

Not everyone is so confident. Khalid Mansoor, former CEO of Engro Power (now at Hub Power) is sceptical of the challenges to do in-situ gasification. Engro Power has entered into a public-private partnership last year with the Government of Sindh to exploit the coal deposits in the Thar region, using more traditional mining methods.

6.2 Pakistan's water crisis

Pakistan has a long history of developing and managing water infrastructure, and has the largest contiguous irrigation system in the world.[250] Despite this irrigation infrastructure and access to world's highest peaks, Pakistan is fast moving from being a 'water stressed country to a water scarce country.'[251] The total renewable water resources decreased from 2,961m³ per capita in 2000; to 1,420 m³ per capita in 2005;[252] and less than 1,000 m³ per person today.[253]

The problem is not due a lack of rainfall or other sources of water but rather inadequate resource management. Pakistan spent 96% of its nearly 170 billion m3 of water withdrawn in 2000 on a relatively wasteful agriculture and did not store enough for power generation.[254] According to World Bank data, Pakistan only stores 30 days of river water, while India stores 120 days and the Colorado River System in USA has storage capacity of up to 900 days of water usage.[255] Although constructing mega dams to store more water has been politically infeasible, the Government's Water Vision 2025 document envisions five new dams to come online.[256]

6.2.1 Innovation to support water sector development

STI could improve reservoir management by preserving existing water resources. Dr Mohammed Akram Chaudhary has led a multi-year, desertification control project in Pakistan's south-eastern Cholistan desert. Chaudhary and his team constructed a series of specially designed storage ponds spaced 10km apart to capture rain water across a 26,000 km2 area. This project has been a success and there are plans to set up similar storage ponds in other deserts, such as Thar and Thal (in northern Sindh and southern Punjab, respectively).

STI could support more efficient irrigation methods. Flood irrigation is predominantly used in Pakistan but this is highly wasteful. One promising approach experimented by the Pakistan Council for Research on Water Resources (PCRWR) and NIAB is drip irrigation. A drip irrigation trial not only cut down on water usage by as much as 70% but has also resulted in better yields.[257]

STI could also help provide clean drinking water. PCRWR provides standardisation and referencing services to industry. It houses Pakistan's first, and only, national water quality laboratory system that provides testing services to other entities within and outside the government. It has created a filter-based water purification system at a fraction of what comparable internationally available techniques would cost. Unfortunately, PCRWR has failed to fully commercialise it.

6.3 Responding to climate change

The recommendations of the Planning Commission's Task Force on Climate Change (see section 5.3.3) primarily focus on adaptation rather than mitigation measures.[258] They included increasing water storage capacity by constructing major dams; developing heat and drought resistant crops through biotechnology; adopting more efficient irrigation practices; increasing milk and meat yield from animals that are less vulnerable to climate change; improving water regulations in coastal areas and deltaic regions; and aggressive (re-)forestation programmes.

A number of government bodies are responsible for the overall response to climate change and the implementation of these recommendations, including the Ministry of Environment, Ministry of Agriculture, Food, and Livestock and MOST. The Ministry of Environment acts as the lead agency yet it has a staff of only four people in its Clean Development Mechanism Cell whereas there are several hundreds in China (and perhaps India). The Task Force's report calls for renaming the Ministry of Environment as the Ministry of Environment and Climate Change and making the Prime Minister's Committee on Climate Change the apex policymaking body in the area.

Although the government has lagged behind, some communities have not. Mahjabeen Abedi chairs the board of Leadership in Environment and Development (LEAD) International, a 12 country international NGO based in London. Even though the government has not yet demonstrated sufficient leadership in this area, communities are already beginning to act as they are forced to adapt to the changing climate. 'People and communities close to the ground reality are really smart in adapting and surviving' says, Abedi, who is also the author of Green Pioneers that documents the stories of some of such people and communities.

There are a range of opinions about climate change in Pakistan. Ali Habib, the Country Director of Worldwide Fund for Nature, criticises the Pakistani government for focussing too much on adaptation rather than conservation measures. 'If you focus on adaptation as a central core of your climate change policy, then you have already missed the opportunity for conservation', says Habib.

6.3.1 Innovation in alternative and renewable energy technologies

Although some infrastructure exists in the country to support the development of renewable energy technologies, it is far from capable of delivering the kind of innovation that is necessary. The Alternate Energy Development Board and Pakistan Council for Renewable Energy Technologies are designed to help commercialise clean energy technologies. They have little, if any, capability or experience of commercialisation.

There is little development of alternative energy systems within the organised engineering sector in the country. The Hydrocarbon Development Institute of Pakistan is an exception. It has been single-handedly credited with introducing a large scale switchover from petroleum to a relatively cleaner Compressed Natural Gas (CNG). With 4,000 CNG stations and more than 2.5 million vehicles, Pakistan leads the world in CNG use.

Much of the development of alternative energy systems takes place outside the organised engineering sector in informal and semi-formal engineering set ups. Shah Kamal is the founder of Alternate Energi, a wind turbine manufacturing company that has received media attention in recent years. He continues to experiment, tinker and invent despite the lack of formal support. In the absence of appropriate government incentives or procurement policies, the commercial market for wind turbines hardly exists. Kamal's turbines are largely bought through NGO money for villages far away from the grid. The lack of interest of the organised engineering sector could be because it does not currently find enough commercial opportunity in the alternative and clean energy technology sector. It may decide to move in at a more opportune time.

6.4 Innovative approaches to poverty alleviation and climate action

6.4.1 Market-driven approaches to address poverty alleviation

When that happens, the non-profit, global social venture fund, Acumen Fund, might be an important part of the story. It seeks to address problems of global poverty by providing 'small amounts of philanthropic capital, combined with large doses of business acumen' to enterprises that serve poor communities. Acumen's investments focus on delivering affordable, critical goods and services, such as health, water, housing and energy, through innovative, market-oriented approaches. Acumen Fund has been investing in Pakistan since 2002. It has a portfolio of $7.7 million in committed capital to a number of businesses, including a low-cost housing company, a corporate dairy farming business, focusing on yield improvement in the dairy business, an affordable micro-drip-irrigation business.[259]

Acumen Fund's market-driven approach and its ability to listen to, and help develop, bottom up innovation are the most interesting aspects of its model. Clean and renewable energy innovation in Pakistan could benefit from a wider implementation of Acumen-style interventions. Considerable work needs to be done to provide alternative energy solutions that are needed by their customers, and to create markets at a price point where they could become sustainable businesses themselves. This is precisely the challenge that Pakistan's current public sector-driven approach to innovation in this area has struggled to address.

6.4.2 Technology to mitigate the impact of climate variability

Although climate science is a relatively new area of research in Pakistan, the technology to deal with some of the consequences of climate change was already on display immediately after the floods in 2010 struck. Even back in 2005 when the earthquake struck the North Western Frontier Province, Pakistanis came together in that their hour of need like never before. Information networks, drawing on mobile phones, SMS, twitter and Facebook, sprang up across the country to support relief and rescue and later fundraising efforts.

Particularly important was the use of geographical information systems. In 2005, a number of international and local academics established the Relief Information Systems for Earthquakes- Pakistan (RISE-PAK). This web-enabled platform provided socio-economic and demographic information to help various rescue and relief agencies to coordinate their operations. RISE-PAK was so successful that it was profiled around the world as an exemplar of how technology can support relief operations during a disaster.[260]

Harvard University's Professor Asim Ijaz Khwaja was one of the founders of RISE-PAK. Although he and his colleagues succeeded in providing the initial impetus, they failed to encourage relief agencies to feed information back into the system, thereby reducing its usefulness. 'We were also not geared towards institutionalising RISE-PAK into a standalone sustainable business entity,' says Khwaja.[261] A local team of economics and computer science academics from LUMS ran the platform for a couple of years before the initiative died down. However, RISE-PAK experience was on hand in 2010. A number of projects, such as Pakistan Flood Maps- a joint venture between Dr Sohaib Khan of LUMS and the Space and Upper Atmospheric Research Commission, as well as others, such as UShahidi, One Response Pakistan, and On the Ground in Pakistan, sprang up almost immediately in the aftermath of the floods.[262]

6.5 Thinking strategically about climate change

Climate change is an area in need of greater focus and action by Pakistan. Many countries in the developed world, are adopting proactive approaches that view climate change as major opportunity.[263 264] Increasingly, developing countries are beginning to look at climate change in a similar way. The UN Climate Summit in Copenhagen reached an accord that included $10 billion of additional climate related assistance to developing countries in the short term (2010-2012) and estimates of up to $100 billion per year by 2020.

Developing countries differ in their ability to innovate. Yet innovation, from the development of technology through its adoption, adaptation, demonstration and large-scale implementation, will be a key component of a Global Climate Deal whenever that becomes a reality. Except for some influential developing countries, such as China, India, Brazil and South Africa, the majority of developing countries are unlikely to seize the opportunity afforded by a Global Climate Deal since they lack effective systems of new knowledge creation and innovation.

Pakistan must ensure that a Global Climate Deal is sympathetic to the unique challenges facing less influential, developing countries, such as Pakistan, whilst also addressing its national interests. This could be achieved by creating a National Strategy for Climate Change Resource Mobilisation that brings together all the disparate actors in Pakistan needed to implement an integrated effort in key areas, including policy formulation, regulation and public procurement; governance and capacity building; and knowledge and innovation.

In addition to bridging the gaps in the knowledge, policy, and regulatory frameworks, Pakistan must develop a comprehensive policy towards cleantech innovation including, the review of existing energy (clean tech) innovation system of Pakistan and strengthening it through creation of bridge programmes (e.g. incubators, accelerators, challenge grants etc.) and / or new institutions (e.g. along the lines of TERI in India, KISTEP in Korea, NEDO in Japan, and Carbon Trust Innovations in UK) to deal with technology transfer, indigenous technology development, and local innovation.

Text Box 15: Sustainability and Agriculture

Agriculture sector can prove to be a major input to energy, climate, and business sustainability in particular and social sustainability in general. For example Shakarganj Mills Ltd. a major sugar making unit installed a plant to produce energy from bagasse through cogeneration. The approach is highly successful and reveres with a number of policy directives such as use of local resources, reduction of green house gasses, recycling of bio-waste. Packages Limited is using wheat straw since 1980s in order to make paper owing to scarcity of wood within the country and rising prices of wood in the international market which resulted into the development of an innovative Chemical Thermo Mechanical Pulping process. Wheat straw which was being utilized previously for cattle feed found a better use and Packages Limited established a complete supply chain around it that not only generated employments for many but also brought about social impact through providing higher prices to farmers and sustaining the climate.

Pakistan is growingly becoming water scarce country and the agriculture is considered going to be one of the most effected economic sector. Focused irrigation practices such as drip irrigation can allow conserving and optimally using this scare resource in the times to come. Similarly, the flood maps can allow developing mechanisms to store and subsequently utilize this mass quantity of water which goes unexploited otherwise and even devastates a large body of crops every year.

Government needs to start initiatives and engage society at large in order to utilize such untapped potential of agriculture sector resources. Business community, researchers and scientists, public sector institutions, and media, need to debate and set agenda as to how this untapped potential can be better exploited for a sustainable development.

7. Collaboration

Dr Arshad Ali is the former Director General of the School of Electrical Engineering and Computer Sciences (SEECS) at NUST. Several years ago he stumbled across an opportunity to collaborate with a professor at California Institute of Technology, who was working on a project for European Organisation for Nuclear Research (CERN) in Geneva, Switzerland. Today, SEECS hosts an impressive array of international collaborations with the likes of Stanford Linear Accelerator (SLAC) and North Carolina State University in USA; University of West England and University of Reading in UK; Ajou University in South Korea; and China's Beijing Institute of Technology.

SEECS' success and portfolio of international collaborations is broadly reflective of Pakistan's. By and large, Pakistani scientists and institutions have sought to collaborate with other developed countries in North America and Europe. Collaborative ties with the emerging scientific powers of the developing world, such as BRIC countries, are notably weak and those with other Islamic World countries are weaker still. In a curious way, Pakistan's scientific collaborations both support and contradict the long-standing principles of its foreign policy and make for some interesting observations. And this landscape may be changing with the as new scientific powers of the developing world emerge and the global scientific landscape undergoes a transformation in the coming years.

This chapter identifies opportunities and barriers to collaboration between Pakistan and the wider international scientific community and global economy. This chapter reviews patterns of Pakistan's collaborations globally and with OIC member countries. It also looks at different policies, programmes, and initiatives that could strengthen these activities.

7.1 International collaborations

7.1.1 Global patterns of collaborations

International collaborations have acquired a new impetus in the last few years. The return of a large number of foreign PhD scholars has created opportunities for scientific collaborations between their parent institutions in Pakistan and their host universities abroad. Traditionally, Pakistani scientists have sought to collaborate with scientists from developed countries, especially USA, UK, Germany, Canada, and Japan. While the absolute number of jointly written papers has grown over the years, these countries have continued to remain important scientific partners. Between 2000 and 2008, China, India, and Saudi Arabia have gained importance. Internationally authored papers tend to have a greater impact (measured as citations per paper) than papers written by authors within the country (see table 7-1). The average impact of almost all papers seems to have grown over time. In 2008, for instance, papers co-authored with US, Indian, and Swiss scientists tended to attract, on average, 4.84, 5.05, and 6.82 citations, respectively.

These collaborations are not surprising. Some of these countries have longstanding historic ties with Pakistan, such as UK and USA, or large Diaspora populations, such as Saudi Arabia, that are more likely to collaborate with Pakistani scientists. Others are becoming more important through programmes of scholarships and exchanges, such as EU, South Korea, and China. HEC has also worked with the Fulbright Commission to massively scale their programme for Pakistan to support scholarships in US universities for women and in social sciences.

Top-10 Global Collaborators (2000)	5-year Count	Citation	Impact
Pakistan	5054	4545	0.899
United States	456	1282	2.811
United Kingdom	423	789	1.865
Germany	180	415	2.306
Canada	78	126	1.615
Japan	70	97	1.386
Saudi Arabia	54	79	1.463
China	48	135	2.813
Italy	46	210	4.565
Sweden	45	92	2.044
Switzerland	43	161	3.744
Top-10 Global Collaborators (2004)	**5-year Count**	**Citation**	**Impact**
Pakistan	6428	7293	1.135
United States	481	1509	3.137
United Kingdom	407	1298	3.189
Germany	186	534	2.871
Japan	105	210	2.000
Canada	102	347	3.402
Saudi Arabia	72	52	0.722
Italy	71	368	5.183
France	58	208	3.586
Australia	57	149	2.614
India	54	180	3.333
Top-10 Global Collaborators (2008)	**5-year Count**	**Citation**	**Impact**
Pakistan	12516	21862	1.747
United States	952	4008	4.840
United Kingdom	801	3339	4.169
Germany	394	1291	3.277
China	332	781	2.352
Canada	303	887	2.927
Japan	250	613	2.452
Korea (ROK)	173	448	2.590
India	161	813	5.050
Saudi Arabia	156	243	1.558
Switzerland	145	990	6.828

Table 7-1: Pakistan's Top 10 Academic Collaborators in the World

7.1.2 Patterns of Collaboration within the OIC

The affinity between Pakistan and other Islamic World countries has often not translated into actual collaborations. In 2000, a Pakistani scientist was eight times more likely to collaborate with a US scientist (its international collaborator of choice) than with a Saudi scientist (its collaborator of choice within the Islamic World). In 2008, this scientist is still six times more likely to collaborate with an American scientist, and Saudi Arabia retains its position as the collaborator of choice within the Islamic World. In 2008, a Pakistani-Saudi collaboration is likely to be a third as fruitful as a Pakistani-American collaboration in terms of its impact (impact factors of 1.55 and 4.84, respectively). Saudi Arabia, Malaysia, Turkey, Bangladesh, and Iran form Pakistan's top-5 collaborating countries within OIC in 2008. With the exception of Saudi Arabia (impact factor 1.55), Pakistani collaborations with the Islamic World are perhaps as impactful as with global collaborations (lowest impact factor is 2.66, 3 out of ten are greater than 5).

It is difficult to conclude whether if there is a greater trend of scientific collaborations with OIC member countries over and above the natural tendency to seek greater international collaborations. If there is, there are few institutionalised mechanisms to promote such collaborations. Those that do exist, such as Inter-Islamic Networks (two of which are hosted by Pakistan) and the SESAME Project (Synchrotron Light for Experimental Applications in the Middle East) have not yet had a major impact on co-authorship.[265] This is something that the HEC, and broader OIC scientific leadership, must support.

7.1.3 Overcoming the securitised image of Pakistan

The security situation in Pakistan has been a major barrier to collaborations (see section 5.1.2). An International Centre of Physics patterned along the lines of Trieste's International Centre of Theoretical Physics was being built at Quaid-e-Azam University campus in Islamabad but been delayed due to security considerations.[266] Even more ambitious plans to establish several Universities of Engineering and Technology with the collaboration of a number countries, such as China, Sweden, Austria, Germany, France, and South Korea, may have been shelved partly because of the security challenges facing Pakistan and the inability of foreign professors to take up residence in Pakistan.[267]

There are exceptions, such as Abdus Salam School of Mathematical Sciences (see textbox 1-1). However, the securitisation of Pakistan's international image significantly increases the cost of collaboration for Pakistani scientists. The Government could help alleviate some of these costs by supporting travel of Pakistani scientists abroad. This has been done, to some extent, through HEC's travel grants programme. This and other similar programmes need to be evaluated and further expanded.

Top-10 OIC Collaborators (1996-00)	5-year Count	Citation	Impact
Saudi Arabia	54	79	1.463
Turkey	39	90	2.308
Egypt	15	29	1.933
Iran	14	14	1.000
Morocco	13	115	8.846
Malaysia	11	6	0.545
United Arab Emirates	10	9	0.900
Jordan	9	12	1.333
Syria	9	8	0.889
Kuwait	8	4	0.500
Top-10 OIC Collaborators (2000-04)	**5-year Count**	**Citation**	**Impact**
Saudi Arabia	72	52	0.722
Turkey	39	93	2.389
Malaysia	25	45	1.800
Iran	22	43	1.955
Bangladesh	18	43	2.389
United Arab Emirates	15	25	1.667
Egypt	13	29	2.231
Kuwait	12	24	2.000
Morocco	12	48	4.000
Kazakhstan	9	5	0.556
Top-10 OIC Collaborators (2004-08)	**5-year Count**	**Citation**	**Impact**
Saudi Arabia	156	243	1.558
Malaysia	90	242	2.689
Turkey	85	308	3.624
Bangladesh	65	329	5.062
Iran	63	168	2.667
Egypt	54	196	3.630
Kuwait	53	169	3.189
Indonesia	30	135	4.500
United Arab Emirates	23	160	6.957
Jordan	21	143	6.810

Table 7-2: Pakistan's Top 10 Academic Collaborators in the Islamic World

7.1.3.1 Need to rethink donor agendas

In recent years, the securitisation of the international debate on Pakistan has meant that the donors' priorities have always matched with a science-driven development agenda for Pakistan. As terrorism has occupied donors' agendas towards Pakistan, funds for science and innovation have dried up. If Pakistan is to believe in the ability and importance of science and innovation in helping overcome the socio-economic challenges it faces today and to divert precious resources from short-term urgent needs to long-term investments in science and innovation, its partners ("donors") must also embrace the idea and their funding priorities must reflect this long-term view. International development assistance played a crucial part in Pakistan's first green revolution (see section 3.2.1) and there is a clear need, today, for the international donor community to develop broad-based lending strategy for Pakistan that includes science and innovation as its critical ingredient.

There are some indications that this is beginning to happen. In recent years, donors have aggressively support education (USAID and UKAid), agriculture (USAID and AusAID), Healthcare (UKAid), technical training (GIZ and others), etc. But this support remains fickle, at best, and sometimes ineffective and counter productive too. There is certainly a need for sustained efforts and people to people contacts that are the essence of science and innovation, greater transparency and accountability of donor money and agendas, and the need to work with the donors to evolve local priorities than these be imposed form outside.

7.2 International R&D programmes

7.2.1 Pakistan-US S&T Cooperative Programme

The Pakistan-US Science and Technology Cooperation Agreement is the most successful programme to foster bilateral collaborations between Pakistan and the international scientific community. It is co-managed by the National Academy of Sciences in USA, and MOST and HEC in Pakistan. This programme solicits research proposals from academic and research institutions that must be approved and funded separately by both Pakistani and US sponsors. Both parties fund their respective side of the collaboration.

Four funding iterations have been successfully completed so far supported by significant resources committed by both sides, particularly from Pakistan. Funded projects include capacity-building in the area of anti-microbial resistance in Pakistan; understanding and controlling plant disease complexes to remedy cotton leaf curl virus in Pakistan; setting up a forensic services and research centre; telephone-based speech interfaces for non-literate users; low cost ICT for the poor, such as open-source rural-scale telephony systems; and assessments of the impact of climate change on glaciers in HKH. The majority of these collaborations bring together foreign and Pakistani researchers. A large minority include researchers of Pakistani origin working in US universities, who partner with their counterparts in Pakistan. Engaging Disapora communities is another important mechanism to establish international collaborations.

US commitment to working with Pakistani scientific institutions and universities has deepened over the years with new Centers of Advanced Studies in Water, Energy, and Agriculture and Food Security being launched at 3 universities paired with sister schools in the US.

7.2.2 British Council Links and INSPIRE programmes

Begun in 2004, the British Council's Joint Higher Education Links Programme has resulted in 50 linkages between universities in Pakistan over two phases of the programme (in 2007 and 2009).[268] Whereas the US programme is jointly funded, this Links programme is funded entirely by the Pakistani Government. Several Pakistani participants of the Links Programme have complained about the value for money that they have received in these partnerships. They have suggested that the British Government should pay for the UK component of the research partnerships. HEC is currently seeking part-funding of this programme from the British Council along the lines of the US S&T Cooperation programme.

The Links Programme is slated to transform into a new and comprehensive International Strategic Partnerships in Research and Education (INSPIRE) programme.[269] [270] In Pakistan, the INSPIRE programme has led to broader higher education partnerships at higher leadership levels, policy dialogues and talented researcher exchange programme, and is even exploring split PhD programmes between Pakistani and UK universities.

The Pakistan-US S&T Cooperation and British Council Links programmes have been crucial in initiating international collaborations for Pakistani universities. More needs to be done to expand the range and depth of these collaborations. Similar programmes could be established with other scientifically advanced countries, such as Brazil, Russia, India, and China, as well as other important developing countries, such as South Africa, Turkey, and Malaysia.

As the capacity of Pakistani universities and research organisations grows, these programmes may need to be structured in a manner that provides a greater value of money for Pakistani counterparts. Many of these initial programmes have had a capacity building character. However, capacity-building per se should not the sole aim. Rather, equal research partnerships could be designed where both parties bring resources to the table and the results of the research could be leveraged to provide long lasting socio-economic benefits. It is also important that donor's priorities match Pakistan's development needs.

7.2.3 Other programmes supporting international collaboration

Except for the Pakistan-US S&T Cooperation and British Council Links programmes, systematic attempts to promote STI collaborations remain relatively weak in other areas.

The notable exception is agriculture where Pakistan has a considerable history of fruitful partnerships. PARC cooperates with institutes in 40 countries in Asia, Middle East, Latin America, Africa, Europe, Australia and North America. There are currently sixteen cooperation protocols between Pakistan and China.[271] The Australia- Pakistan Agricultural Linkages Programme is a A$6.6 million programme managed by the Australian Centre for International Agriculture Research on behalf of AusAID. It focuses on market development, academic linkages, academic partnerships and joint R&D projects. Separate programme elements exist for the mango, citrus, and dairy sectors.[272] A similar agreement has recently been signed between Pakistan and USA under the Bilateral Strategic Dialogue.[274] A number of USAID-funded projects are already underway in support of agricultural market development, research and commercialisation in Pakistan.

7.3 Regional collaborations

7.3.1 COMSTECH

Pakistan championed the creation of the OIC Standing Committee for Science and Technological Cooperation (COMSTECH) in 1981 (see 1.1.3). It is responsible for promoting intra-OIC S&T collaboration, as well as creating political support and policy coordination between OIC member countries.

COMSTECH runs a number of programmes to support basic capacity building within OIC member states. This includes programmes to provide research and travel grants, equipment and equipment maintenance grants, an inter-library loan service, a literature search service, and training courses. COMSTECH has not been very successful at promoting research collaborations among Islamic World countries primarily because of the lack of financial resources and a lack of a mandate to do so.[274]

In the absence of strong financial support from its stakeholders, COMSTECH has turned to jointly funded programmes with a number of international organisations such as the IDB, Academy of Sciences for the Developing World (TWAS), International Federation of Science, and World Health Organisation that provide research grants to scientists from the Islamic World.

While these programmes have been a ray of hope for scientists from the most disadvantaged OIC member states, their impact on promoting research collaboration is not clear. COMSTECH does not collect any data or has not carried out analysis on the impact of its programmes on promoting research collaborations. With the exception of the IDB-funded Intra-Islamic Networks and Early Harvesting Projects Initiative, none of these programmes require mandatory collaboration between member states.[275] Despite enthusiasm at the governmental level, Pakistan's meaningful participation in these projects has been limited.

Beyond COMSTECH, the intra-OIC scientific collaboration has been seriously hamstrung by the desire of a few countries to go it alone and an unwillingness of the richer members to carry the burden of the less fortunate. Efforts to promote intra-OIC collaborations have been marred because of the organisation's need to secure consensus among 57 member states. As the champion of COMSTECH, Pakistan could lead calls to reform this organisation, perhaps through the creation of a smaller forward bloc of countries more willing and better able to collaborate.

7.3.2 COMSATS

The Commission on Science and Technology for Sustainable Development in the South (COMSATS) is an inter-governmental organization created on the invitation of the Prime Minister of Pakistan in 1994 and is headquartered in Islamabad, Pakistan. The current membership of the Commission includes 21 developing countries from three continents. A Network of Centres of Excellence comprises 17 scientific and technological organisations from across member countries. COMSATS seeks to advance the social, economic, and environmental development of the member countries through South-South and North-South collaborations, organising events, promoting knowledge sharing and dissemination, and sponsoring scientific activities.

7.3.3 SAARC

South Asian Association for Regional Cooperation (SAARC) is a regional grouping of countries in South Asia, namely, India, Pakistan, Bangladesh, Sri Lanka, Nepal, and Bhutan. Created in 1985, it initially focussed on collaboration within the areas of economic, technological, social, and cultural development. Afghanistan joined in 2005 and other countries, such as Iran, China, and other Central Asian Republics, are interested in becoming members.

SAARC, along with its free trade agreement, SAFTA, has been hamstrung because of the relationship between its two largest members: India and Pakistan. There has been a virtual stalemate on serious issues at the governmental level. Some cultural programmes and unofficial exchanges due to personal links and contacts have been possible over the years. It is therefore unsurprising that co-authorship between scientists from India and Pakistan are on the rise despite a lack of government support (including, an onerous visa process) for such undertakings.

7.3.4 EU Framework Programmes

European Union Framework Programmes have remained a relatively unexplored territory by Pakistani scientists. Yet a few Islamic World countries, most notably in the Mediterranean region, have tapped into them. Participation in EU Framework programmes provides an excellent opportunity for Pakistan's scientific community to tap into European science and its R&D funding networks. As Pakistan better integrates with European research universities through HEC funded scholarships programmes, engaging the EU Framework Programmes should merit serious consideration by HEC, MOST and the Ministry of Foreign Affairs.

7.3.5 Unexplored avenues

Although some informal relationships exist, a number of other avenues have yet to be explored. With the exception of China, and to a lesser extent, India, Pakistan does not have a clear strategy to engage with the emerging BRICS. These countries are going to play a considerable role in S&T in any future scenario. These relationships need to be cultivated systematically.

Deepening Pakistan's collaboration with China must be prioritised, along with Turkey and Iran (the two science leaders in the OIC). The recent commitments by China towards the establishment of China Pakistan Economic Corridor (CPEC) may be leveraged to create more robust cooperation in science and innovation. A systematic set of programmes, such as collaborative grants (along the lines of Pakistan-US Cooperation Programme), exchange programmes and scholarships could be extremely valuable. This could be done from the platform of the ECO has the additional advantage of reaching out to Central Asian Republics and their strong Soviet-era scientific capabilities. Pakistan could explore collaborations with Commonwealth countries. However, given its somewhat chequered relationship with the Commonwealth, it is unclear if this would be a suitable mechanism to facilitate collaborations with these countries.

8. Prognosis

8.1 A new discourse on rationale, priorities, and funding

Nadeem ul Haque is the former Deputy Chairman of the Country's Planning Commission – the government's think tank responsible for carrying out long-range planning and advising on investment decisions of the Government of Pakistan. An economist by profession, Haque is deeply critical of the development paradigm and discourse in the country. "There is too much focus on projects, not enough on people," he says. "This hardware based approach to development needs to be replaced by a more 'software' based approach if we are to succeed in our development challenges". A strategy for developing science and innovation in the country, he believes, must seek to create an environment where excellence could be rewarded and debate and dissent are encouraged. But there is a vast difference between lofty visions and policy actions on the ground.

Under the leadership of Minister Ahsan Iqbal, the Planning Commission recently launched the Vision 2025 that acknowledges this social 'software' of development. Introducing the Vision, Iqbal notes:

> Pakistan Vision 2025 lays down a foundation to put Pakistan on a fast track of development with the ultimate goal of transforming it to become one of top ten economies in the world by 2047, its first centenary. By 2025, it envisions Pakistan among top twenty five economies of the world and a upper middle income country. More importantly, creating a balanced platform for development by building strong social foundations without which any dream of becoming a developed country shall remain elusive.

The fundamental challenge for the Planning Commission and relevant Ministries then is of creating a society that rewards excellence, innovation, and transparency rather than mediocrity, rent-seeking, and empire building in every sphere of its operations, public, private, and in academia. This society, when created, is likely to send a fundamentally different set of signals to its people as it provides them with the necessary space to unleash their scientific talents and innovative spirits in support for a well-thought through set of societal goals and personal ambitions.

It is this struggle for the creation of an 'innovative society' that any development planner or policy-maker must address head-on as he (or she) seeks to create a science and innovation-based development paradigm for Pakistan. In this new paradigm of thinking about science and innovation, it is perhaps as important to address the 'why' (rationale), 'what' (priorities), 'how' (mechanisms), and 'who' (mix) as it is to answer 'how much' of science and innovation to fund from the public purse. Getting these details right is fundamental to creating a virtuous cycle of investment and returns from science and innovation.

This is precisely the development discourse that this inaugural review of Pakistan's Science and Innovation Landscape hopes to catalyse in the Pakistani society.

8.1.1 A ‘balanced’ funding model for science and innovation[276]

As a means to jumpstart this conversation – and not as a final verdict – on how the funding of science and innovation needs to be organised in the country, this report proposes a new public funding paradigm for STI that has the following two characteristics:

First, it seeks to undo the imbalances of STI funding within the country in terms of relative shares of funds provided by public, private, and academic sectors as well as their use such as basic and applied research, commercialisation, and innovation.

Second, it seeks to create an all-encompassing STI system from basic research to knowledge creation (in the public domain) and profits (in the private realm) that will jumpstart the wheel of science and innovation funding within the country and establish the much needed social contract.

This new model proposes a three tiered structure for public funding of science:

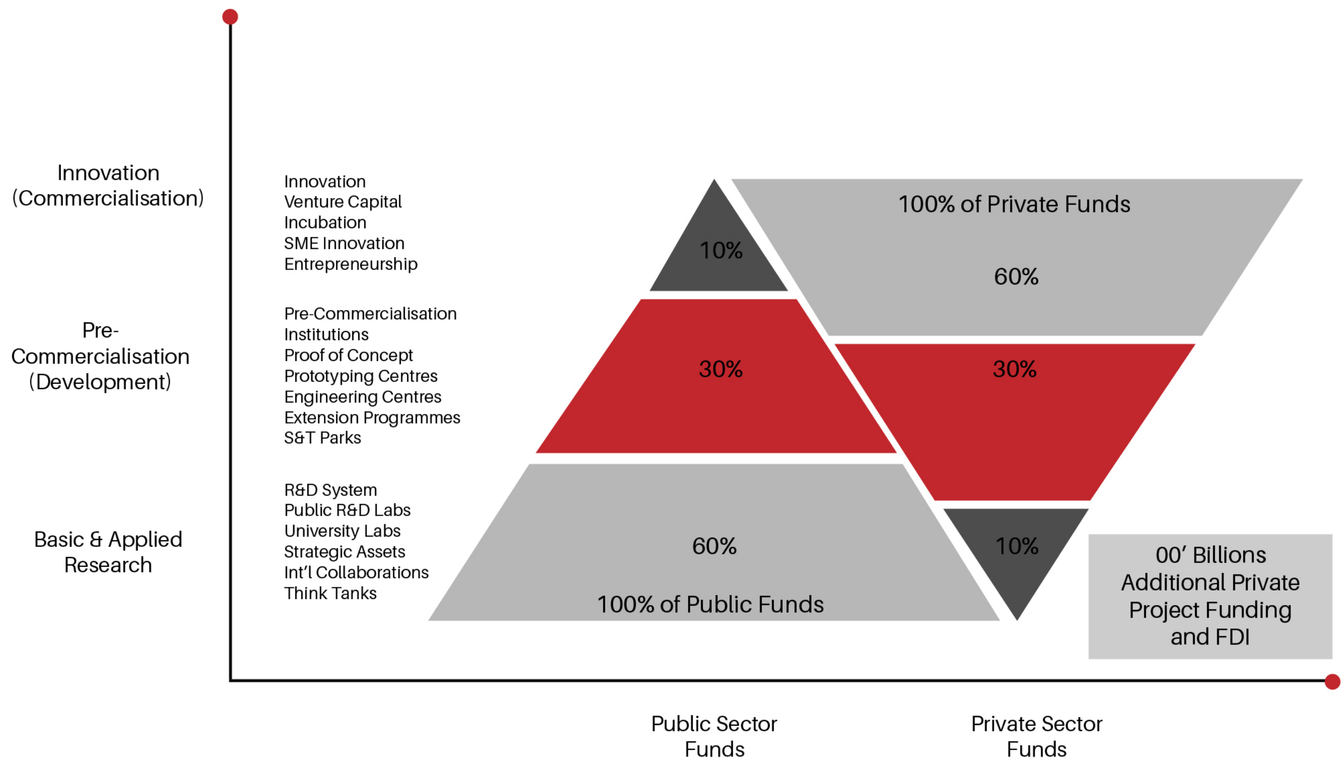
First, about 60-70% of the total public funding could support basic and applied research (divided between 30% and 70%, respectively). Because of the public character of basic (and some applied) science, this will attract much less private sector funding. An aspirational target would be to have around 10% of basic and applied research to be funded by private sector in 10-15 years time.

Second, about 25-30% of the total public S&T funding could be allocated for pre-commercialisation (or development) to help commercialise R&D. This near-market effort must be jointly funded by the public and private sectors beginning, initially, at a 50:50 level but perhaps gradually moving towards a 20:80 balance between public and private funding.

Third, a smaller portion, perhaps 5-10% of total public S&T funding could be dedicated towards innovation (or commercialisation). These funds could initially be made available to private and non-profit entities seeking to promote innovation across a range of different sectors. Over time, private sector must take a greater share in funding of innovation, aspiring (perhaps) a 10:90 balance between public and private sectors.

Creating a system of public funding along the line suggested above will not be a straight forward task that can be achieved merely through a policy decree. It will require an extensive dialogue between various important sectors of the society – in particular between public-private and university-industry – and a genuine attempt to build trust and a partnership between the three.

It is also critical that private sector becomes an important participant in Pakistan’s science and innovation system as it provides the key to commercialisation and impact. However, if private sector must contribute a substantial sum (at least Rs 50 billion by 2020 under the most ambitious assumptions of public funding) to fund of science and its commercialisation, an economic opportunity at least 10-15 times greater that size for it to be worth its while to do so. This will require a series of programmes and interventions to promote of university-industry collaborations (see chapter 2), innovation and entrepreneurship (see chapter 4), quality and relevance (see chapter 1), and prioritisation and a broader support for STI within Pakistani society (see chapter 5). These themes form the basis of the recommendations.


Innovation (Commercialisation)
Pre-Commercialisation (Development)
Basic & Applied Research
Innovation
Venture Capital
Incubation
SME Innovation
Entrepreneurship
Pre-Commercialisation
Institutions
Proof of Concept
Prototyping Centres
Engineering Centres
Extension Programmes
S&T Parks
R&D System
Public R&D Labs
University Labs
Strategic Assets
Int'l Collaborations
Think Tanks
10%
30%
60%
100% of Public Funds
100% of Private Funds
60%
30%
10%
00' Billions Additional Private Project Funding and FDI
Public Sector Funds
Private Sector Funds

8.2 Strengths and challenges

With a track record of accomplishments spanning over 65 years, Pakistani STI offers many strengths. There are several challenges that need to be addressed before the highly attractive opportunities that STI in Pakistan offers, not only domestically but also internationally, can be fully materialized.

8.1.1 Strengths

8.1.1.1 The talent and resilience of Pakistan's people

Pakistan's most precious resource is its people. They are some of the world's most talented and hardworking, who have fought hard in the face of tremendous challenges and against all odds to survive and thrive in virtually every sphere of life. The potential of Pakistan's Diaspora communities comprising accomplished professionals, and scattered across the world, to contribute to Pakistan's development (whether formally or informally) should not be overlooked.

8.1.1.2 Recent revival of investment in STI

Recent investments in Pakistan's science and Innovation through the HEC have created an opportunity for Pakistan's universities to engage seriously with the global scientific enterprise. It can provide an important element of a forward looking strategy to build upon in the coming years and decades. The significant capability that exists within PAEC, strategic and defence research organisations and a small number of private sector universities should be drawn on to sustain the momentum of this revival. This revival has led to important trends in human capital, especially increases in university enrolment and the number of PhDs (see section 2.2) although at the expense of college education and technician training (see section 2.4.1). Gender ratios have also improved (see sections 1.4.1 and 2.4.2).

8.1.1.3 A track of record of success

Pakistan is no stranger or novice to the benefits that S&T can deliver if made a national priority. From the Green Revolution in the 1960s; through the nuclear programme during the 1970s and 1980s; to the missile development programme in 1990s; Pakistan stands in good stead for another push to use S&T to achieve national goals. Since a large number of Pakistan's current scientific leaders were part of these successes, this push should tap into the appetite among Pakistani scientists for a new national mission, particularly within the agriculture and nuclear energy establishment.

8.1.1.4 The emergence of an entrepreneurial eco-system

Recent years have witnessed a selective, but growing, entrepreneurial ecosystem within Pakistan. Particularly visible in ICT, it is gradually infiltrating other areas as well. In characteristic Pakistani fashion, this entrepreneurship has been led by Pakistani people rather than active governmental efforts or policy to support the growth of entrepreneurship in the country.

8.1.1.5 Opportunities to exploit a number of emerging areas in science

New and emerging areas where Pakistan did not traditionally have a strong research base include material sciences, mathematics and computer science. Other potential bright spots include environmental science, biochemistry, biotechnology and genetics, chemical engineering and immunology.

Pakistan is considerable diversity in the underlying economic structure of the country. These include traditional areas of strength such as defence, agriculture and textiles and light manufacturing, as well as new areas, such as ICT.

8.1.1.6 Potential of Pakistan's defence and strategic sectors

Considerable capability and capacity exists within Pakistan's defence and strategic sectors that could, with due checks and balances, be shared with or brought to bear on civilian sectors of Pakistan's economy. There are historical demonstrations, such as in USA after World War II, of the important role military procurement can play in promoting civilian STI.

Pakistan could benefit immensely from spin-on and spin-off of its defence and strategic capability by encouraging private sector participation and pushing publicly held entities towards becoming more commercially and export-oriented. A joint development and public procurement framework to open up defence and strategic sectors, including spin-off and spin-on activities, could unleash a new wave of innovation with Pakistan's civilian economy.

8.1.1.7 Untapped and abundant natural resources

Pakistan's geography is diverse and vast, blessing it with considerable natural resources, including water, coal, sunlight and minerals. Exploiting these resources responsibly could help Pakistan address its major sustainability challenges.

8.2.2 Challenges

8.2.2.1 Formulation of national vision for Pakistani science

Pakistan needs to develop a clear a vision for how STI benefit it economically, socially and culturally. Efforts are needed to enhance the popular support for science, in the absence of which science budgets have fluctuated from one government to another and have often been easy targets for cuts during tough economic times. The science community needs to make its self more relevant and be more vocal to make the case for science and what it can deliver.

8.2.2.2 Rationalization of science policy and implementation infrastructure

Pakistan's STI policy infrastructure needs to be much more coherent and coordinated.. NCST has not been able to provide the required science policy leadership. Below NCST, there is a plethora of different ministries, departments, and institutions that have been created over years, leading to conflicting or duplicating objectives, funding priorities, and a hodgepodge of policy initiatives. A major restructuring and based on a philosophy of devolution could be a step in the right direction. As policymaking and its implementation moves to sub-national level, this may lead to opportunities for greater innovation.

8.2.2.3 Need for a more comprehensive strategy to develop human capital

A comprehensive strategy is needed to fully realise the potential of the human capacity. Efforts to improve higher education, although laudable, may be unlikely to deliver results without parallel efforts to improve basic and primary education and develop technical and vocational training while keeping in view the future demands of various sectors of economy.

8.2.2.4 Developing a tradition of research commercialisation

Public sector research organisations that constitute the vast majority of funded R&D have been unable to commercialise the results of this research. Bridging organisations, such as STEDEC and PATCO, are unlikely to succeed where others, such as PCSIR, have failed because, they too, lack the organisational flexibility and incentives structures to successfully commercialise research.

Private sector R&D is almost absent in Pakistan. Innovation, particularly science-driven innovation, is not a hallmark of Pakistani business organisations. Addressing this would help establish a virtuous cycle of private investment and returns from R&D. Despite promising signs of successful university-industry collaborations (see section 4.5.3), they remain relatively few and far between. Such collaborations need to be more systematically inculcated.

8.2.2.5 Pakistan's international image

The regional geopolitical instability in which Pakistan finds itself has led to a securitised image of Pakistan internationally that unfortunately does not reflect the full reality of the country and the talents and aspirations of its people. The heavy focus on security creates significant barriers for the international community to engage with Pakistani science and help Pakistan meets its own national development priorities.

8.2.2.6 Limited levels of international collaboration

While international scientific collaboration has picked up in recent years, it is confined to a limited number of countries. Pakistan could benefit from collaborating with other developing countries, in general, and Islamic World countries, in particular. Collaborations with ECO and BRIC countries, especially China, should be explored systematically.

8.3 Recommendations for Pakistan

This section lays out a set of recommendations to jumpstart a virtuous cycle of science, technology and innovation investments leading to significant impacts through new knowledge creation, generation of economic activity, and social and human development. These recommendations can be broadly classified under three broad and overarching themes:

First, a holistic perspective and a comprehensive policy regime needs to be developed that includes all the related factors and linkages that impinge upon STI system. The STI system must be rationalised to deliver seamlessly. This requires that appropriate mechanisms and policies are in place for all actors – domestic and foreign, public and private, defense and civilian – within the eco-system to play their respective appropriate roles. Recommendations 8.3.1, 8.3.2, and 8.3.3 deal with this broad theme.

Second, the proper and effective functioning of the national STI system depends on the right 'hardware' and 'software' and any gaps in these realms need to be bridged. These require investments in infrastructure and creating the environment necessary for science and innovation to flourish. Recommendations 8.3.4, 8.3.5, 8.3.6, 8.3.10, and 8.3.11 deal with this broad theme.

Third, launching a small number of well-designed "mega-initiatives" will trigger the demand for the products of the STI system. These launch initiatives will make supply and demand interdependent and must be big enough to make a substantial impact (and returns) and be visible enough to enhance the profile of science and innovation within the society. A judicious selection of a portfolio of small number of mega-initiatives (up to 3) can deliver the much needed boost to Pakistani science and society. Recommendations 8.3.7, 8.3.8, and 8.3.9 deal with this broad theme.

Some specific initiatives needed to implement the approach outlined above will are included in the recommendations below:

8.3.1 Create a National Dialogue on Science and Innovation

A National Dialogue on Science and Innovation is necessary to create grass roots and higher level, political support for science. This would put in place the building blocks for a social contract between the scientific community and wider Pakistani society and lead to a greater societal ownership of science and innovation. This Dialogue should set out a clear national vision for science by: identifying short to medium term targets and opportunities where science can have socio-economic impact; restating the rationale for how science can strengthen the country's internal and external security; and arguing for the value of a more scientifically literate and innovative society and how this could be achieved over the longer term.

Participation in this National Dialogue should be inclusive, involving government, universities, research establishments, the business community and civil society. Carried out over perhaps a year, it could consist of carefully designed events and meetings that convene policymakers, scientists, industrialists, entrepreneurs, innovators and students. It could also benefit from the involvement of international partners, such as the British Council, IDRC, TWAS, COMSTECH and AAAS.

8.3.2 Establish a National Science and Innovation Task Force to review the STI policy infrastructure

A National Science and Innovation Task Force should be established, reporting within a period of six months to the Prime Minister in his capacity as Chairman of NCST. The Task Force needs to make recommendations in three priority areas. First, NCST needs to be transformed into a more effective and fully functional advocate of S&T in national policymaking. Second, the national STI infrastructure needs to be rationalised to address Pakistan's priority needs at both levels of formulating and implementing policy. Third, the success (or lack thereof) of the commercialisation mandates of public sector S&T organisations should be reviewed and, where necessary, their organisational missions should be redefined, strengthened or eliminated. Room should be made for greater private sector leadership and participation. This Task Force may be positioned under and impartial body like the Planning Commission that is able to look at the entire science, technology, and innovation infrastructure without being a part of it.

8.3.3 NCST should develop a new funding structure for science and innovation

NCST should develop a national political consensus on a new STI funding structure to correct imbalances between the funding of basic and applied research, development, commercialisation and innovation. This structure must define a clear set of expectations and objectives, milestones, allocations, and targets in a transparent and participative manner that streamlines funding across various elements of the innovation value-chain. It should also encourage participation of the private sector.

NCST must consider creative ways of funding science, such as ring-fencing certain funds, instituting an R&D tax (as has been the case with the ICT R&D Fund), as well as using Goal Oriented R&D programmes, Science Prizes, and Research Challenges to spur innovation.

8.3.4 Formulate a comprehensive human capital strategy

An appropriately empowered Government Commission should be tasked with formulating a comprehensive strategy to realise the potential of its human capital. This strategy needs to adopt a system-wide view of the STI value-chain. Without a holistic approach, piecemeal action is unlikely to deliver results.

Basic and primary education is perhaps the weakest link where the greatest opportunities lie and the greatest rewards could be made. Resources need to be spent more efficiently. The quality of teachers needs to be improved perhaps through teacher training programmes and educational leadership academies. Attention must also be paid to wider socio-economic and cultural factors that hinder progress, such as inculcating a better work ethic, infusing the value of work, and promoting creative and rational thinking among school children and students.

8.3.5 Develop a sustained policy effort to support a culture of private sector driven innovation

A focussed national programme is needed to promote collaboration between industry, academia and the public sector. This needs to establish trust and create success stories that could catalyse the process. Specific policy actions, such as tax incentives and credits, procurement policies, foundational investments, and innovation awards, could promote private sector R&D and innovation.

R&D incentives do not operate in isolation of general economic policy and management regime. This could create an economic opportunity that could increase tenfold the size of private R&D investment being sought, unleashing economic growth that would be unparalleled in Pakistan's history.

8.3.6 Develop a focussed policy to support entrepreneurship

The Government of Pakistan and relevant public sector entities, especially the Ministry of Finance, Ministry of IT and Telecom and MOST should develop a comprehensive policy that celebrates and promotes the emerging entrepreneurial culture within the country, particularly within the ICT industry, and extend it to other science-based industries, such as agriculture, animal sciences, biotechnology, metallurgy and materials, chemicals and pharmaceutical, as well as engineering.

This could involve a number of policy actions, ranging from tax incentives to the intelligent use of public procurement policies. In addition to the hardware of entrepreneurship, adequate attention must be paid to the software, too, that seeks to create role models of successful entrepreneurs. Doing so will require, at the very least, putting in place a comprehensive framework for public support for entrepreneurial centres, incubators, S&T Parks, as well as support for technology SMEs. Fostering entrepreneurship will also require that mechanisms be set up to capture and massively replicate informal innovation in the economy and society.

8.3.9 Create a comprehensive effort to leverage science and innovation within the agriculture and veterinary sector

Pakistan's agriculture and veterinary sectors are ripe science and innovation to deliver some extremely obvious benefits. Despite the advancements of the 1970s, Pakistan's agricultural sector suffers from low productivity and yield levels and a considerable performance gap between model farm and average yields. The veterinary sector – with its promise of a "white" revolution, despite of some of the lowest yields among competitors – presents opportunities of unfathomable proportions. However, these could be unlocked only through significant deployment of science and innovation but also by addressing a governance, policy, and implementation deficit.

A national effort to capitalise on Pakistan's immense potential in these sectors will require creating a seamless science-to-business interface involving a number of different pieces of the puzzle including education, research, extension, commercialisation, and business. It will also require creating an STI supply chain where the supply and demand are better aligned and geared towards adoption and replication of new science and technology.

8.3.8 Embark on a mega-initiative to address Pakistan's sustainability challenges

Pakistan needs a mega-project to address the major sustainability challenges it faces in light of a fragile natural environment and impending energy and water crises. This national research programme will need to be on the scale and scope of earlier successes, such as agriculture in 1960s and nuclear sciences and technology in 1970s and 1980s. Doing so will require tremendous resolve and mobilisation of all possible resources and entities of the state and private sector at every level, and making use of each element of the STI value-chain. A more open PAEC in collaboration with Pakistan Agricultural Research Council could jointly lead the proposed effort.

Pakistan must ensure that a Global Climate Deal is sympathetic to the unique challenges facing less influential, developing countries, such as Pakistan, whilst also addressing its national interests. This could be addressed by establishing a National Strategy for Climate Change Resource Mobilisation that brings together all the disparate actors in Pakistan needed to implement an integrated effort in key areas, including policy formulation, regulation and public procurement; governance and capacity building; and knowledge and innovation. Pakistan also needs to build capability to carry out research that adopts a multi-disciplinary, system-wide view towards sustainability issues.

8.3.9 Open up the defence and strategic sector(s) to the mainstream STI system

While Pakistan has a fairly strong track record of science and innovation within defense and strategic sectors, much of this capability – even production – lies within tightly controlled state (defense) owned facilities thus severely limiting an array of commercial spillovers from this activity. Not unlike the developed world, there is a significant opportunity to use the defense' need for innovation as a means to jumpstart innovation within the mainstream economy and society. This will require creating an enabling environment for greater private sector participation in these areas; better STI coordination between public, private, and defense sectors; and exploiting spin-off and spin-on opportunities.

An appropriately empowered Commission should be set up to develop and implement a framework for opening up Pakistan's defence and strategic sectors to private sector participation. This Commission should comprise leaders of Pakistan's defence and strategic STI assets, such as the Special Plans Division, Ministry of Defence Production, PAEC, NESCOM, and key civilian assets. Suitable representation of the private sector is vital.

8.3.10 Create a Science and Innovation Alliance of OIC member countries to demonstrate transformative leadership in STI

MOST and Ministry of Foreign Affairs should take proactive leadership and create a like-minded coalition of OIC member countries that are willing and able to work together to transform their collective and individual destinies through science and innovation. Pakistan could seek a Science and Innovation Alliance of countries facing similar challenges with complimentary capabilities and assets. This could be under a newly expanded D8+2 umbrella, including the Group of 8 Developing Countries (Pakistan, Iran, Turkey, Malaysia, Nigeria, Egypt, Indonesia, and Bangladesh) and 2 like-minded oil rich countries of the Gulf, such as Saudi Arabia and Qatar.

8.3.11 Capitalise on unexploited avenues of international collaboration

MOST and the Ministry of Foreign Affairs should develop and implement a strategy to exploit the possibilities of as yet unexplored avenues of international collaboration. This could involve a systematic set of programmes, such as collaborative grants, exchange programmes and scholarships could be extremely valuable. The Pakistan-US S&T Cooperation provides model for collaborating with other scientifically advanced countries, such as BRIC economics, especially China, as well as other important developing countries, such as South Africa, Turkey, Iran and Malaysia.

Pakistan should increase its multilateral engagements with international agencies, especially agriculture and climate change- related, and pursue other mechanisms so far neglected, such as the European Union Framework Programmes.

As its initial champion, Pakistan is well placed to lead calls to reform and strengthen COMSTECH and to realise its promise of facilitating international collaborations.

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which would be otherwise so sound that no one could object to them but in them I found nothing but statements that the Qur'ân contains knowledge of such and such nature... Then I pondered over the Qur'ân itself to understand the foundational principles of its composition and as far as I could grasp, I found no contradiction between these principles and the modern knowledge... "

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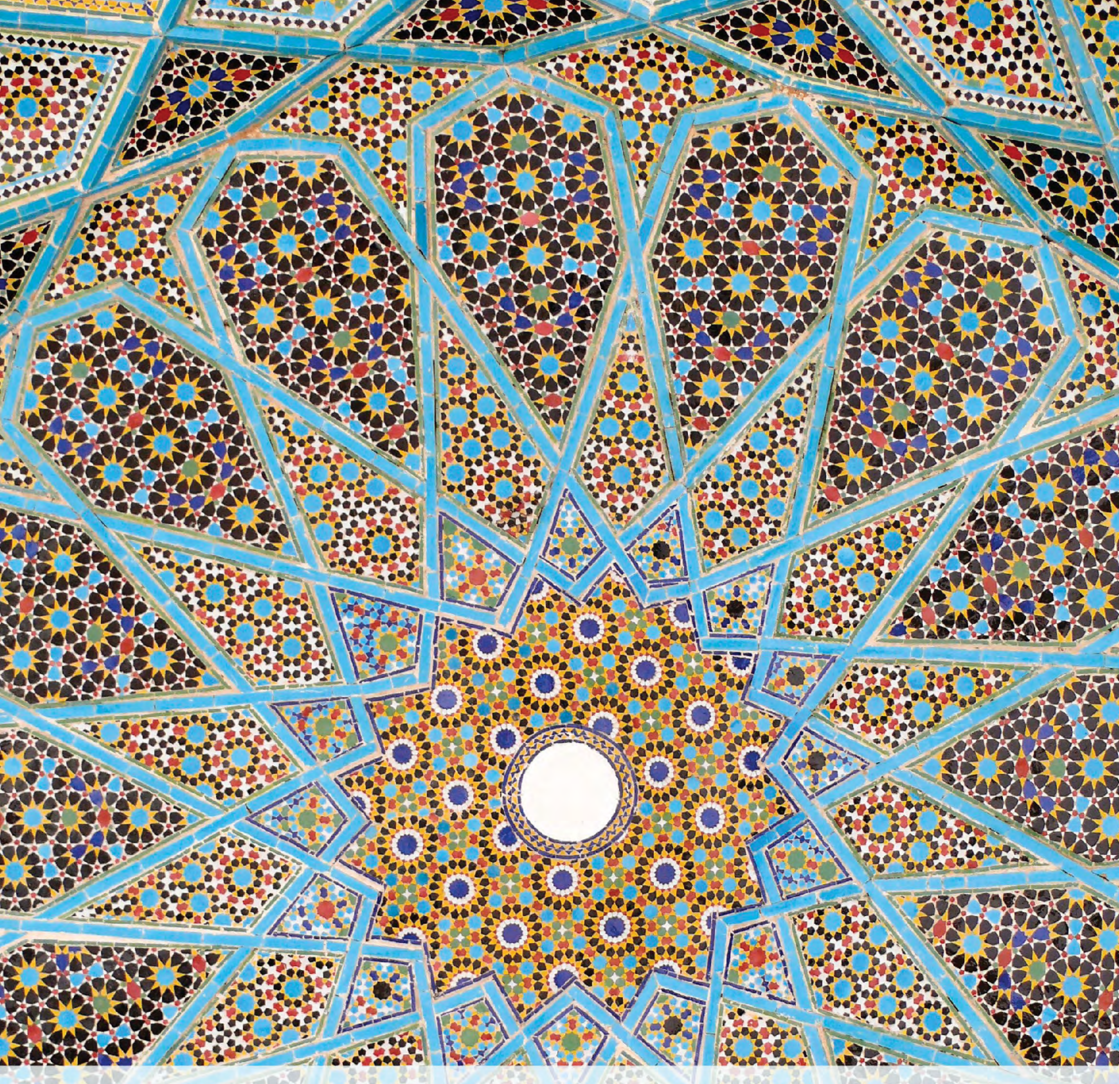

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