INSTITUTE FOR POLICY REFORMS

IPR BRIEF

May 2018

General Recommendations to Promote Science, Technology, and Innovation in Pakistan

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About the Author

The writer is former federal minister and Chairman HEC of Pakistan. He has over a thousand publications. He is Fellow, Royal Society London, received the prestigious UNESCO Science Prize, was Coordinator General of COMSTECH, an OIC Ministerial Committee. He has been honoured by the Government of Peoples' Republic of China. Research centres in China and Malaysia have been established in his name.

About IPR

1. **STI Strategy and Action Plan:** Establish a clear short, medium, and long terms vision, strategy, and action plan for integrating STI into all sectors of the government ranging from industry and agriculture to health, communications and social services.
2. **Provide Leadership for Implementation of STI Vision**: Support the STI vision with a strong and visionary leadership at the level of the Prime Minister for its effective implementation and position the mandate for STI in the office of the Prime Minister to ensure strategic implementation.
3. **Foresight Exercises for Migration to Knowledge Economy:** Conduct regular Foresight exercises, aligned to the Sustainable Development Goals (SDGs) and integrated across all line Ministries, in consultation with all stakeholders, to help in building functional innovation systems and to transition to knowledge-based economies.
4. **Financing of STI Action Plan for Establishing a Knowledge Economy:** Allocate appropriate funding for implementation of STI policy in national development plans including a sizeable allocation for R & D which should be at least 3% of GDP and progressively increased to 5% of GDP. Similarly, investments in education should be at least 5% of the GDP gradually increasing to 10%, with at least 1.5% of GDP being allocated to higher education.
5. **Institutional Reforms:** Undertake institutional reforms including the restructuring of institutions of higher learning and research, those providing testing, quality and standards related services, as well as legal and financial institutions.
6. **Support and Develop Private Industry to Contribute Meaningfully to a Knowledge Economy:** Increase absorptive capacity of private industry to productively use external and internal knowledge for manufacture and export of high technology products by making government funding available for venture capital, for hiring highly skilled personnel.

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7. **Promote High Technology Manufacturing and Exports:** Grant "pioneering status" to high tech industries with suitable long-term tax free status to promote manufacturing and exports in high tech fields, provide government insurance for under-writing risk in new high technology ventures and establish a revolving Innovation Fund to support indigenous high technology development in the public and private sector.
8. **Promulgation of National Education Emergency:** Declare a National Education Emergency so that the appalling state of education in Pakistan can be tackled on a war footing and allocate at least 10% of GDP for education to improve access as well as quality of primary, secondary, technical, vocational and higher education.
9. **Promotion of World Class Research:** Establish world-class research institutions in cutting edge fields including biotechnology, nanotechnology, material sciences, artificial intelligence, genomics, bioinformatics, mechatronics, industrial processing, agricultural technologies and other important areas. These should have internationally recognized, peer-reviewed scholarly capacity for academic and industry collaborative research, and undertake investments in the shape of setting standards, funded projects, research grants for faculty
10. **Highly Qualified Manpower**: Create critical mass of high quality professionals (scientists / engineers) and technically trained manpower (progressively increase to 2500 highly qualified professionals involved in R & D per million population). This will require a dramatic change in salaries and other incentives to reduce brain drain and re-attract diaspora to fulfill human capital needs for future growth and expansion.
11. **Industrial Clusters:** Establish regional industrial clusters accompanied by technical training institutions (Fachhochschule model) to ensure cost effective, relevant, demand-driven and collaborative industrial production. The China Pakistan Economic Corridor (CPEC) should become a "knowledge hub" of such multiple industrial and training clusters focusing on the manufacture and export of engineering goods, defense products, biotechnology products, pharmaceuticals, etc.
12. **Institutions for Metrology, Standards and Testing:** Establish concrete, world-class infrastructure for Metrology, Standards and Testing including international standards, to facilitate consistent high-quality product manufacture and exports.
13. **Link Foreign Direct Investment to Knowledge Transfer**: Government should link the approval of all foreign assistance and Foreign Direct Investment projects to mandatory knowledge transfer, so that at least 5% of the cost of such projects is set aside for training and indigenous capability development, leading to national self-reliance.

Specific Steps to Establish Centers of Excellence in Following Key Fields:

1) Robotics and Artificial Intelligence

The fourth industrial revolution that is upon us is marked by breakthroughs in a number of fields, including autonomous electric vehicles, robotics, artificial intelligence, nanotechnology, quantum computing, Internet of Things, 3D printing, genomics/bioinformatics, and humans with embedded electronics. Self-driving cars are being developed by all major manufacturers. This may eventually result in many major manufacturing companies going out of business as it could become far easier and cost effective to have robotic taxis on the road that would be available in minutes, replacing the need of having a personal car. It has been predicted that bots will be taking over many spheres of our business activities, thereby improving business efficiencies and improving customer experience. Powered by artificial intelligence (AI), they are being used to give free legal advice, public transport directions and cooking tips. This trend will continue to grow so much so that lawyers and doctors could be partly replaced by robotic systems.

Cloud services are now evolving with combination of AI, thereby creating an exciting new dimension. A major US company has already introduced more than 20 "cognitive services" including image analysis (computer vision) and language comprehension. Predictive analytics (data mining, forecast trends) are also being offered by some companies. Facial recognition technology could lead to more effective security systems. It has been predicted that in 2018, we will enter the Robotics 3.0 era with smarter robots capable of ubiquitous sensing and connectivity, cyber-physical fusion, autonomous capabilities (such as cognition, decision-making, learning and adaptation). They will also be capable and more human-friendly multimode interactions. A related disruptive technology that is developing rapidly is that of quantum computing. Quantum computers will outperform super computers and many companies are investing heavily in this field. Pakistan needs to prepare itself and strive to become a world leader in these new and emerging technologies.

Blockchain (distributed ledger technology) is another fast evolving field. It has so far underpinned bitcoin and other cryptocurrencies, so that it was looked at with some disdain. But now it will find use in real estate, intellectual property protection as well as in organizing Internet of Things (IoT) devices.

2) Engineering

A tragic reality of our industrial sector is that 60% of our industry is in the field of textiles, which constitutes a very small portion (6%) of the world market. We are absent from the major world market sectors such as engineering goods, pharmaceuticals, IT industry, ship building, electronics, biotechnology products, new materials etc. The single most important sector for industrial development is that of engineering. This requires the development of the technological, financial and physical infrastructures, and creating a seamless integration with emerging trends of global production systems. The lack of high quality technical education has been identified as one of the reasons for the limited progress in the engineering sector. There is also a need to develop design engineering capabilities, databases, and infrastructure, create testing laboratories and instruments, and initiate public -private partnership in projects leading to innovation of new products and processes. Universities need to be strengthened and Centers of excellence established in various branches of engineering sciences. An excellent beginning in this direction has already been made by initiating a project for the establishment of the Pak-Austrian University of Applied Science and Engineering ("Fachhochschule") in Haripur Hazara.

3) Materials Science, Nanotechnology

The development of new materials is critical for economic growth and competitiveness. Composites are finding applications in many industries, particularly in the areas of defence, electronics, engineering, transport, energy and sport. We need to open up of centres of excellence in metallurgy, and departments for advanced studies in new materials in various universities; establish centres for the development of polymeric and photonic materials; focus on the establishment of geo-data and geo-mapping centres; and research and development centres for the exploitation of resources of gemstones. Pakistan has a strong mineral base as compared with many developing countries, but it has not been able to extract maximum potential benefits from it.

Nanotechnology is a fast emerging field of materials science and it is offering a myriad industrial opportunities. It involves the study and use of materials of very tiny dimensions ----dimensions at the scale of a billionth of a meter ----referred to as a "nanometer" (nm)! When materials are reduced to this size, their properties undergo dramatic changes and fascinating new industrial products have been developed in a whole range of fields based on nanotechnologies. The applications range in fields as diverse as surface science, organic chemistry, molecular biology, semiconductor physics, micro fabrication, energy storage systems, water purification, and others. The corresponding applications are found across a wide variety of fields including medicine, engineering, electronics, energy, new materials for water purifications, catalysts in industry etc. Hundreds of billions of dollars are now being invested in various fields to make new types of nanomaterials with exciting new applications and improved properties and performance.

Carbon nanotubes that have found wide applications in new material development including electronic items. It is estimated that there are now more than two thousand different items in the market based on nanotechnology that include sunscreens, cosmetics, surface coatings, food products, gecko tape, silver in food packaging, clothing finishing materials, disinfectants and household appliances, surface coatings, paints and outdoor furniture varnishes, pharmaceuticals, electronic sensors, and fuel catalysts. Bullet proof paper is being developed based on Nano cellulose. Clothing are being infused using nanotechnology allowing them to survive longer against wear and tear and keep cool in the summer. Tennis balls are being coated with nano materials so that they can last longer and surgical goods as well as other metal items are now coated with nanomaterials making them tougher. Videogame consoles as well as car surfaces are being coated with nanomaterials to make them scratch-resistant. Nanotechnology is also being employed in the fast-developing field of tissue engineering.

4) Biotechnology and Genomics

Biotechnology involves the application of living systems or organisms to make products. We need to focus on recent developments in biotechnology and genetic engineering in order to enhance crop yields and create disease resistant, drought resistant and salt resistant crops. Agriculture is the largest income and employment-generating sector of Pakistan's economy. However, it continues to suffer from low productivity. The major reasons for our low productivity as compared to India or Egypt are lack of seed varieties, resistance to pests and diseases, low genetic potential, drought and high temperature stress. The losses in agricultural output due to salinity/water logging are more than 30 billion rupees per annum, and post-harvest losses for fruits and vegetables alone are up to 60 billion rupees every year. A sustained growth rate of five to six per cent in agriculture is imperative to ensure a rapid growth in national income, macroeconomic stability, fair distribution of wealth and a reduction in poverty. This can be realized by exploiting the unachieved potential of all the sub-sectors of agriculture, diversifying agricultural production towards high value crops, and conserving land and water resources. Industrial biotechnology has huge potential both in agriculture and health.

Amazing developments are also occurring in the health arena, through the application of gene editing techniques such as CRISPR-cas9. These techniques result in changes in the genetic structure of organisms,

thereby altering their characteristics. Genome editing in this manner has been used in various ways to alleviate genetic disorders in animals and are likely to be employed soon in the clinic to treat human diseases, particularly of the eye and blood. Genome editing tools are also being employed to expedite crop and livestock breeding, engineer new antimicrobials and control disease-carrying insects.

5) Agricultural Engineering

Various rapidly emerging branches of agricultural engineering offer Pakistan enormous opportunities for increasing agricultural output, as well as increased yields, disease resistance, drought tolerance and improved quality of fruits and vegetables suitable for export. Focus should also be on production of high quality dairy products for export, horticulture, tissue culture, and fisheries.

6) Electronics

The electronics industry is one of the world's fastest growing industries. It is a key enabler of growth and innovation, underpinning many important industries including automotive, Information and Communication Technologies (ICT), consumer appliances, defence, biomedical appliances and other scientific equipment and devices. Despite its huge growth potential, Pakistan has significantly lagged behind in the development of its electronics industry. For the electronics sector to emerge as one of the key drivers of growth in Pakistan, we need to focus on human resource development especially in the emerging areas of Digital Signal Processing (DSP), Optics, Digital Communications (DC), and Microelectronics; development of indigenous R&D capabilities; establishment of VLSI design and training centres; and development of specialized technology parks with quality infrastructure to support the concentration of high-tech industries.

7) Renewable Energy

New technologies in renewable energy based on solar, wind, hydroelectric and other sources will be progressively replacing conventional energy from fuels. This is already visible in the sharp drop in prices of solar energy during the last 3 years. The recent developments range from printed solar cells to new types of cells that convert both heat and light to electricity and have conversion efficiencies of over 50%. Pakistan needs to invest in research and production of these new energy technologies.

8) Energy Storage

There is huge interest in the development of energy storage systems that will allow cars to operate on electric batteries with driving range of above 500 km, and with charging times of less than a minute. The combustion engine powered vehicles will disappear from the roads across the world and will be replaced by electric vehicles. Pakistan needs to establish top class research and development centres in this rapidly emerging field so that it can be a world leader.

9) Regenerative Medicine

The field of tissue engineering and regenerative medicine is developing rapidly with the advent of stem cell technologies and with other developments. Translational stem cell research directed at organ repair needs to be given high priority. Centers of Excellence can be established linked to hospitals to provide patient care.