Papers and Proceedings
pp. 1–26

Allama Iqbal Lecture

Science, Technology and Innovation for Socio-economic Development

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Knowledge has now become the key to socio-economic development and countries investing in science, technology and innovation are progressing rapidly, leaving others far behind. Amazing innovations are transforming our world at a mind boggling pace. They are disrupting economies as conventional technologies recede into the past and are replaced by new products and processes. I will begin by giving a few examples from some important fields.

Biotechnology involves the application of living systems or organisms to make products. One application of biotechnology has been in the production of golden rice which addresses the problem of vitamin A deficiency in children in developing countries. It has been estimated that about 200 million children and about 20 million women suffer from vitamin A deficiency in 122 countries resulting in 1-2 million deaths annually and 500,000 cases of irreversible blindness. Swiss and German scientists have developed a new genetic variety of rice, named “Golden Rice”, which contains a provitamin A built into it. The latest variety of this rice “Golden Rice 2” contains sufficient provitamin A to provide the daily requirement of vitamin A via consumption of some 75g of rice.

Why do you get mangoes only in the summer? The reason is that there is a certain biological clock built into every plant which tells the plant when to flower and when to fruit. In a collaborative study involving scientists from Peking University and Yale, it was found that the gene controlling the biological clock is the DET 1 gene. Turning such genes on could result in the round the year availability off-season crops. This could have a major impact on the world food supply.

Some scientists have succeeded in inserting genes responsible for luminescence in deep sea jelly fishes and fire flies into orchids. The result is orchids which glow in the dark just as fireflies do. Others have combined these genes with spider proteins that stick to cancer cells and make them glow. This allows surgeons to identify cancerous cells easily. In another development the polio virus has been genetically re-engineered to treat a fatal form of brain cancer. Genetically modified mosquitoes have been prepared to combat malaria, and FDA recently approved certain genetically modified mosquitoes to combat Zika virus. In China genetically modified cows have been developed which produce milk almost identical to human milk. Obesity is also now been linked to certain

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genes and gene therapy is being developed to tackle obesity. The process of ageing is now being understood in genetic terms and a number of genes have been identified that are involved in the ageing process. Research in this field has led to the discovery of a number of compounds that not only slow down the ageing process but actually reverse it! These compounds include one ("resveratrol") found in peanuts, grapes and red wines. When given to mice it made old mice young again, changing their body features also. Another compound "metformin", an anti-diabetic drug, is dubbed as an "elixir of youth" as it was found to extend the life span in animals and prevent cancer. Its clinical testing is presently underway.

Is synthetic life round the corner? Craig Venter in USA has prepared a "minimal genome"—a genome with synthetic DNA which contains just 473 genes essential to life. When inserted into a bacterium whose natural DNA had been previously removed, the bacterium came alive and made a billion copies of itself! Another related area of hot research is that of tissue engineering. Stem cells are now beginning used to repair corneas, damaged hearts, kidneys or even brains. Stem cell research promises to transform medicine as it will be practiced tomorrow.

Do you know that if you cut off the tail of a lizard it grows back. However if you cut off an arm of a person, it does not grow back. Why? Researchers at the Translational Genomics Research Institute (TGen) and Arizona State University (ASU) have recently identified three genetic switches, known as "microRNAs", which may *hold the keys* to regenerating muscles, cartilage, and spinal columns. These switches are able to turn genes on and off, and are associated with the regeneration of tails in the green anole lizard. Do such switches exist and can they be turned on in human beings? An exciting new area of tissue engineering research has opened up.

Another area that promises to transform the world as we know it is artificial intelligence. A cap has been developed which allows mental commands to be transmitted to a small computer. Cars can then be driven purely by thought control and paralysed persons can operate motorised wheel chairs just by mental commands. Artificial intelligence will before long be taking over from humans in almost every area of human activity, and according to Stephen Hawking it poses a huge threat to our very existence on this planet.

The blind can today see with their tongue. Actually we "see" with our brain – the eyes are only a mechanism for image transfer. Wicab, a Wisconsin based company, has developed a tiny camera that is fitted on glasses worn by the blind person. The optical images from it are converted into electrical images and then transferred to a lollipop device that has some 400 sensors. When the blind person places this "electronic lollipop" in his mouth, the image is transferred through the nerves in the tongue to the brain, restoring partial eyes sight. This allows hitherto blind persons to see lift buttons and distinguish between a knife and a fork. IBM has developed a powerful computer named "Watson" which was recently involved in a competition with top cancer specialists. It was found that Watson recommended the same treatment for patients as the oncologists in 99 percent of the cases. Indeed Watson found treatment options that cancer specialists missed in 30 percent of the cases. Military domination of nations may be dependent on the intelligence of the computers.

Another area of intense research is that of new materials. A new class of materials, known as "metamaterials" have been developed that can bend light. Objects covered by such materials become invisible. They are now being used for cloaking submarines and tanks. Two Professors at Manchester university shared the Nobel Prize for chemistry in 2010 for discovering "graphene", a material made of pure carbon that is 200 times stronger than steel. Graphene is now finding a multitude of applications ranging from more powerful batteries, building materials and paper thin televisions to powerful computers and pharmaceuticals. Self-healing materials have been developed. If you fire a bullet into them, the hole created disappears within seconds as the material repairs itself. Paper has been made from powdered stone mixed with a polymer and it is in many ways superior to normal paper.

New materials are having a major impact on a large number of industrial sectors including the electronics, automobile, engineering, polymer and plastic, textiles, construction and other sectors. Recent advances in nanotechnology are leading to exciting new concepts for the development of new materials for the engineering, chemicals, pharmaceuticals, and other sectors. Nanotechnology in health applications cover a wide variety of products involving the development of diagnostic tools, drugs and vaccine delivery, development of new type of surgical devices, treatment of various diseases, and detection of different pathogens. Nanotechnology can also affect access to pure water and affect sanitation through development of nano-membranes and nano-clays as well as through water recycling and remediation including the use of nanoporous polymers to purify water and remove toxic metals. Similarly application of nanotechnology in renewable energy through the development of sola r cells, hydrogen fuel cells and nano-photovaltaic devices as well as carbon nanotubes are rapidly developing.

New knowledge, particularly knowledge related to technology, drives the economic systems. Economic agents, including firms and governments, are forced to adapt to technical change in order to survive in a competitive environment. While governments should act as facilitator, technology capabilities must accumulate in enterprises. This will only be possible if we strengthen our universities and R&D organisations and create effective linkages between them and industry. It will be the increasing use of knowledge in the production processes and service industry, which will determine the growth of our GDP.

Our ability to compete or survive in the globalisation of economic systems depends on our commitment towards the development of our human capital and ensuring a continuous learning process within the government institutions and enterprises to create a culture of innovation. Innovation is concerned with enhancing national productivity and national competitive performance. Dynamic innovation systems involve an inter-play between a number of different parts of the society which include the government, private sector, universities and research institutions. The transition of our economy from an agriculture-based economy to a knowledge-based economy involves a mosaic of complex interactions in which a large number of players would be involved. The universities will need to play a central part in this transition through knowledge creation, its use and diffusion of new knowledge into the society through establishment of technology parks, business incubators, access to venture capital and other such schemes.

The new world order requires us to prepare our children to face the challenges of the global economy. This involves a substantially different type of education to be imparted, focused not only on the mastery of subject matters but also on the development of the various other skills such as the ability to think critically, innovate, communicate effectively, work effectively in teams, develop entrepreneurship and risk-taking skills, and the ability to face and manage changes in a flexible manner. This would require a massive focused national effort. While investment towards development of high level S&T manpower is necessary to meet the critical shortage of teachers and researchers, equally important is investment in skill development at technical education and management levels and provision of quality education to the majority of our population. We need to develop and introduce a system of incentives that attracts our brightest youth towards scientific careers and a system, which supports and rewards innovation. This would require investment in building an infrastructure for research and facilities and training institutes for continued training to deepen the knowledge and development of the skills of researchers. We need to strengthen or establish Centres of Excellence in those areas, which are relevant to our social and economic requirements. These Centres should be equipped with facilities provided in the world's best institutions including a top class faculty with internationally comparable pay scales. The scientists or researchers in these Centres of Excellence should be encouraged to work on contract research commissioned by the industry or be allowed a sabbatical for six months to work with industry. The Centres of Excellence should not only be a source of new knowledge but be equipped with state-of-the-art laboratories to provide Metrology, Testing and Standards services. The creation of National Standards, Metrology and Testing facilities are essential for economic development. We need to create knowledge networks through collaboration of government research laboratories and industry at the regional, national, and international levels. Regional knowledge networks can be developed through collaboration of industrial clusters with the local universities. Regional firms in turn must collaborate with each other to share knowledge about latest production practices and quality management. Collaboration between local firms, public institutions, and multinationals are essential to transfer capabilities in jointly executed projects. Our industrial and trade policies must encourage local technology firms and engineering enterprises, through continuous upgrading of technology and skills and access to markets small industry must be encouraged to convert into medium sized ones and medium sized industry into large ones. Collaboration with the relevant international knowledge networks can help our industry enter global value chains. The essential component of a National System of Innovation is the high quality knowledge workers or researchers. Pakistan presently has only about 120 scientists/engineers in per million population engaged in R&D as compared to 2500-3000 scientists/engineers per million population in the advanced countries. We should therefore target to reach a similar figure per million population (500,000 PhD level scientists by 2025) if we are to participate in a knowledge economy.

The changing global face of science is leading to science becoming an increasingly multidisciplinary area in which institutions in many countries must participate together. Technology development is now closely interlinked with developments in various scientific fields, and we cannot expect to become technologically self-reliant unless we have the necessary strength in both basic and applied sciences. Basic science is what feeds the Science Parks where innovation and utilisation is made. It has been shown time and again, that discoveries in the basic sciences of today become the basis of major commercial products of tomorrow. Pursuit of new knowledge and its application for invention should become a part of the social fabric. In a competitive world of knowledge-based economies, keeping abreast with the latest technology is not sufficient but direct engagement in science, technology, innovation and discovery is essential. For this an "out-of-the-box" thinking and bold decision making would be required We need to recognise that policies concerned with human capital development, science and technology and innovation should lead to a raise in GDP per capita, employment generation and poverty alleviation. Consequently, they need appropriate and sustained investments, they take time to work, and they will not be helped by frequent changes in objectives or national commitments.

1. PROMOTING INNOVATION

The three major players in the development of a knowledge economy are universities, industry and the government.* All three thrive on the extent of merit-based competiveness that should be in-built into the systems and on the efficiency of interaction with the other two players. The development of a knowledge economy requires a thorough understanding of the dynamic interplay between research, invention, innovation, and economic growth. Such an understanding allows them to be modulated according to national needs and challenges.

Policies on Education, Science, Technology, Innovation and Entrepreneurship are all intricately interrelated. Entrepreneurship, its growth, survival and competitiveness are dependent on innovation and in a developing country context on incremental innovation. Incremental innovation is about sourcing, absorbing, adapting and diffusing already available international technologies and related knowledge. Incremental innovation depends on the absorptive capacity of firms and according to Cohen and Levinthal only firms with advanced human skills and prior relevant accumulated knowledge can successfully convert external knowledge into incremental innovations. Prior related knowledge helps local firms recognise the value of new information, assimilate it and apply it for commercial benefits.

The World Economic Forum, based on Porter's classification, has categorised the developmental stages of economies across countries in three distinct categories: (i) factor based, where the production and services sector are dominated by low cost labour and resource based inputs. Innovation contributes less than 5 percent in factor based economies, (ii) the efficiency driven stage, which requires modern machinery, better technical and managerial skills and promotion of a culture of firm level learning, iii, innovation and knowledge driven stage; this further advancement needs heavy investment in human resource development, training of a critical number of scientists and engineers, promotion of firm level R&D and life long learning practices. At this stage innovation contributes at least 30 percent to the economy.

While most developed countries in Western Europe, USA, Japan, Canada, Finland and East Asian countries of South Korea and Taiwan are ranked as innovation driven knowledge economies, Pakistan with several other developing countries has been placed in the category of factor based economy, characterised by high unemployment rates and huge shadow economies where large number of businesses operate in informally.

*(The Triple Helix Model, Loet Leydesdorff, Annual Review of Information Science and Technology 44 (2010) 367-417).

The global innovation landscape is not static; it has moved across geographical borders and has shifted from one civilisation to another. In the past three decades only we have witnessed nation after nation achieve economic and social development through structural adjustments of their economies and adopting a path of promoting education, in particular higher education, acquiring and adopting foreign technology for production of high valued goods and services and having diversified their economies from resource based to knowledge based. Public-private partnership and public incentives for encouraging partnerships between local and international firms have played a key role in achieving this transition.

If Pakistan's economy is to grow and survive in an increasingly competitive global market then it too has to transition from factor based towards an efficiency driven, innovation and knowledge based economy. This requires not only a major role by the private sector but also public incentives to encourage collaborations between local businesses and universities, between regional businesses and foreign multinational firms. Almost all developed countries have realised the benefits of what has come to be known as collaborative advantage. In USA for example, the best management schools are moving towards teaching students about collaborative rather than comparative or competitive advantage.

There are numerous benefits of collaboration, particularly for developing countries. Considering the fact that most developing countries lack sufficient numbers of financial and human resources for conducting strategic research, collaboration could be the answer. Collaborating organisations would be able to synergise by sharing their physical, financial and human resources and thereby reducing risks. Collaboration between innovative SMEs helps them grow, achieve economy of scale and enter global value chains. Sharing of capital, tacit knowledge about production techniques and better management and marketing strategies can lead firms towards innovation and knowledge-based production. While inter- laboratory and inter-firm collaboration is important, equally important is collaboration with international laboratories and multinational firms as they provide local firms learning opportunities but access to new technologies, and innovative ways of management, marketing and production.

Excellent examples of research as well as entrepreneurial collaboration exist within Pakistan. We achieved our goal of ensuring defense security not just by investing in nuclear research but also actively forging collaboration between six laboratories located in different regions of Pakistan. Collaboration between our private entrepreneurs and Civil Aviation Authority (CAA) resulted in the building of an international airport in Sialkot. Our engineers built the world's highest highway and manufactured fighter jet in collaboration with China. Policy makers, in Pakistan should draw lessons from these examples, particularly at a time when the nation is facing immense problems related to energy, un-employment and an ever increasing number of people forced to live under the poverty line.

National short and long term goals need to be clearly defined with the help of evidence based research and regular foresight activities. Research on benchmarking innovations in the industrial sectors and incentive structures has to be institutionalised for regular review and evaluation. It is easier to plan and implement incentives when one knows where and when to intervene.

Public incentives can help forge collaborations between enterprises, particularly those working in similar fields to increase productivity, produce value added goods and services and to achieve economies of scale. Incentives help in transfer of technical knowledge from university to industry and to stimulate collaboration between local enterprises and with multinational companies. Incentives may differ in type and form and have to be carefully worked out to suit specific conditions in the industry. They need to be administered with simplicity and transparency and should have a sunset clause [Rodrick (2004)].

Inviting collaborative research projects where R&D goals for each laboratory are clearly defined should encourage collaboration between public research laboratories. Public research funding should be linked to not only advancement of basic and strategic research but a certain proportion be set aside for applied industrial research, for design and development of prototypes and for stimulating R&D in private enterprises.

Industrial clusters should be offered incentives linked to efficient production, value addition, and process and product innovation and for growth in productivity. Incentives for skill development courses for industrial workers and for hiring of high quality engineers should be given priority. Government can also offer incentives in the form of Technical or Engineering Centres that provide design, testing and standards related services.

Our knowledge, technology, innovation and entrepreneurship gap with regional competitors is widening. We are grouped among the technologically marginalised, knowledge and innovation deficient countries in the global rankings. This is an insult to a nation of 180 million people that have the potential to advance, share and contribute to the global technical knowledge. The ICT technologies are making people of Pakistan aware of the global developments whereby they are increasingly realising that their backwardness, hunger, disease and poverty need not be eternal and that the solution to address these problems lies in education, acquisition of scientific knowledge and technology based entrepreneurship.

Pakistan has been struggling to cope with the massive problems that confront it—growing poverty, serious law and order situation, massive illiteracy, closure of large industrial sectors because of lack of competiveness and rampant corruption. The single most important factor that has contributed to this situation has been the poor state of our educational system. Pakistan today spends only about 1.9 percent of its GDP on education. We are therefore ranked among the bottom 9 countries of the world in terms of expenditure on education. An illiterate population can be readily exploited. As a result we have witnessed corrupt politicians coming into power repeatedly through exploitation by feudal landlords and massive rigging of elections.

2. THE FOUR KEY PILLARS FOR PROGRESS IN A KNOWLEDGE ECONOMY

The four pillars of progress are (1) High Quality Education, (2) Science and Technology (3) Innovation and Entrepreneurship, and (4) A Governance System that allows merit to prevail and offers quick and fair justice.

2.1. Education

Pakistan spends only about 1.9 percent of its GDP on education (as opposed to Malaysia’s 30 percent of budget). For a nuclear state like Pakistan it is a shameful reality that we are ranked among the bottom 7 countries of the world, standing at 126 among 132 countries (http://www.nationmaster.com/graph/edu_edu_spe-education-spending-of-gdp). This has been largely due to the strangle-hold of the feudal system on our parliament which has given the lowest priority to education. It is not in the interests of the feudal landlords and rulers to allow an educated society to emerge that will challenge their lordly feudal life styles in which millions of peasants and farmers are exploited and held in virtual slavery. Pakistan did make spectacular progress in higher education after the establishment of the Higher Education Commission in 2002. For the first time in its history, several of its universities were ranked in the top 600 of the world with NUST at a respectable 273 and UET (Lahore) at 281. However this progress came to a grinding halt after 2008, when the budget of HEC was slashed by 50 percent and over 90 percent of the projects frozen. The enemies of Pakistan had succeeded in almost destroying the only sector that was showing good progress. In November 2010 the government issued a notification to shred HEC into pieces in order to protect corrupt parliamentarians. HEC had found that 53 of these national leaders had forged degrees while another 250 had degrees that were suspect. The Parliamentarians hatched the evil scheme to shred HEC into pieces, and it was only on my Appeal to the Supreme Court that this national disaster was averted. The Supreme Court declared the Government notification to shred HEC into pieces unconstitutional and restored its status.

Primary, secondary and technical education remains in a complete mess, with no hope in sight. Ghost schools, where teachers' salaries are paid to servants of the feudal landlords, and illiteracy prevails. True literacy stands at about 25 percent. In an illiterate nation such as ours, and the only one in the world where the feudal system prevails, democracy is just a farce. Corrupt politicians loot and plunder, amassing vast fortunes abroad, while poverty grows and engulfs most of the country, creating ideal grounds for terrorism to grow. Mass migration of talent and businesses abroad has further compounded the situation. USA and its allies have been spending $200 billion annually in their war effort but if they had invested a quarter of this amount in education, particularly in Pakistan and Afghanistan, terrorism could have been tackled at its grass roots.

2.2. Science and Technology

The collapse of the science and Technology institutions in Pakistan is reflected from the fact that the development budget of the Ministry of Science and Technology in 2002, when I was the Federal Minister of Science and Technology, was Rs 6 billion, but it has fallen to below Rs 1 billion now. A country weak in science is forever paralytically dependent on all its needs of technology on others.

Engineering represents the backbone of defense and industry. A wonderful scheme was approved by ECNEC in February 2008 to set up foreign engineering universities in Pakistan with integrated technology parks where foreign companies such as Siemens or Eriksson could set up Research and Development Centres for new product development. Germany, France, Sweden, Italy, Austria and Korea had all agreed to set up their engineering universities in various cities of Pakistan, in which degrees would have been offered by top foreign universities without our students going abroad. This could have saved Pakistan about Rs 100 billion annually which is what our parents spend today to provide high quality foreign education to their children abroad. However the scheme was abandoned in May 2008, as the government had "other priorities than education"—a monumental national disaster!

2.3. Innovation and Entrepreneurship

Unless laboratory level research is translated into marketable products, a knowledge economy cannot be promoted. A number of steps must be taken to make this happen. Firstly Pakistan must have a clear Science, Technology and Innovation policy at the national level. The national technology policy should ensure that no development project is approved on a turn-key basis, and genuine transfer of technology must be an integral part of all development projects. Secondly a country must have a strong Intellectual Property Rights regime that must be vigorously enforced and implemented. Thirdly there should be liberal access to Venture Capital funding to support and foster new start-up companies based on innovative ideas. Fourthly, private sector R & D should be promoted through a dynamic incentivisation process. Lastly, there must be a clear national road map for transitioning from our low value-added economy to a knowledge economy. Such a road map was prepared under my leadership, (a 300 page document entitled "Technology Based Industrial Visio, Strategy and Action Plan for Socio-economic Development") and approved by the Cabinet in August 2007. It clearly lays out the projects that must be undertaken in various sectors such as agriculture, electronics, engineering, information technology, biotechnology, chemicals and pharmaceuticals, textiles etc. An inter-Ministerial committee was formed for its implementation but it lies in government archives gathering dust.

2.5. Governance

The migration from our low value added economy to a powerful knowledge economy just cannot occur unless we have a powerful government of visionary technocrats. The Cabinets of China and Korea comprise the most eminent scientists and engineers in the country. Korea has given the status of Deputy Prime Minister to its Minister of Higher Education, Science and Technology. The present British Parliamentary system of democracy has failed over and over again. We must bring in a Presidential form of democracy and free institutions such as NAB, FIA, Police, PIA, Railways, Steel Mills, FBR etc. from the clutches of the government. They should have their own completely autonomous status and independent merit- based appointment system of the Heads. Without a visionary, honest and technologically competent government that ensures justice and merit, Pakistan cannot progress.

3. LEARNING FROM OTHERS: ESTABLISHING A KNOWLEDGE ECONOMY

There are numerous examples of how poor and weak nations have been transformed into powerful countries within a couple of decades once they have given the highest priority to these factors. We can learn much from them.

In a number of countries in Asia this was achieved with remarkable due to strong and visionary leaderships. Take the case of Singapore. It is a small country with no natural resources. In 1960, it had a small but rapidly growing population of 1.6 million. In the subsequent decades it was transformed into an economically powerful giant, all because of the visionary and honest leadership of one man—Lee Kwan Yew, Singapore's first Prime Minister. He took charge as Prime Minister on 5th June 1959 and governed Singapore for three decades. He established a corruption-free government, ensured the availability of a skilled work force and developed excellent infrastructure, thereby attracting huge foreign investments.

In the period between1964 to 1978, Singapore changed from an import substitution policy to an export oriented one. Between1965 to 1978, the manufacturing sector's share of GDP jumped from 14 percent in 1965 to 24 percent in 1978. The growth rate averaged a remarkable 10 percent per annum and the unemployment rate fell from 10 percent in 1965 to 3.6 percent in 1978. During the subsequent 8-year period (1978-1985), the share of skilled employees in the total employment doubled from 11 percent to 22 percent. The salaries of workers also increased from an average of $18,400 in 1979 to $27,000 in 1985. In the subsequent period between 1986 to 1997, focus was given to niche industries such as electronics, engineering and petrochemicals. The GDP growth rate averaged 8.5 percent and the number of research scientists shot up from only 3,361 in 1987 to 11,302 in 1997. Its GDP increased from US $12 billion in 1980 to US$ 251 billion in 2010. About 3,000 multinational companies have begun operations in Singapore. The biotechnology industry has been given top priority and a number of leading pharmaceutical companies have set up manufacturing plants in Singapore. Singapore continues today to be the fastest growing economy in the world, with an enviable growth rate of 17.9 percent during the first half of 2010.

Relationship between Higher Education Enrolment and Exports in Korea

	1960	1970	1980	1990	2001	2010
Higher Education Enrollment	5%	8.7%	16%	37.7%	68% *(2.6%)	82% *(7.8%)
Exports US$(Millions)	32	660	17,214	63,214	150,439 *(10,000)	466,300 *(20,290)

*Statistics for Pakistan.

In Malaysia, a similar story was repeated under the leadership of Mahathir Mohammed. Malaysia had an economy based on mining and low value agriculture in 1970. In 1980, the GDP of Malaysia was only US$ 26 billion. It made a determined effort to shift to a manufacturing economy. By 2010, its GDP has shot up to US$ 414 billion, and the per capita income now stands at US$ 14,700. Malaysia alone contributes 86.5 percent of the total high technology exports from the Islamic world, such as microchips and semiconductors, a truly remarkable figure.

The transformation of Korea serves as another excellent example. The corrupt democracies prior to 1961 had contributed to its dismal failure—a situation not much different from Pakistan. The foundations of a powerful industrial nation in Korea were then laid by the visionary policies of General Park Chung-hee. He seized power in 1961 and ruled till his assassination in 1979. Korea was a poor country with a per capita income of only US$ 72 in 1961. Today the per capita income stands at a stunning figure of US$ 30,200, while its GDP stands at US$ 1.423 trillion! General Park brought about a radical change with export-oriented industrialisation policies. He mended relations with Japan, and Korea developed rapidly with Japanese investments and technology.

The first lesson to be learned from the progress made by these countries is that a corrupt democracy is the worst disaster that can happen to a country. In Pakistan, there has been far greater average GDP growth under every military regime (General Ziaul Haq, General Ayub Khan, General Pervez Musharraf) than the years of rule under the "psudo-democratic" regimes during the last 64 years. This is surprising but true. Alas the best "democracy" in Pakistan has performed much worse than the worst military regime, in terms of socio-economic development. What is responsible for this shocking but undeniable fact? The reason is that the British Parliamentary system of democracy just cannot function properly in a country with massive illiteracy and a feudal system that is averse to the promotion of education, science, technology, innovation and entrepreneurship. The present democratic system, by and large, results in the most corrupt and the most powerful becoming members of Parliament and then becoming Ministers. Their state of immorality is reflected from the fact they have no hesitation in forging their degrees to become eligible for elections, in their greed for power. About 51 members of the present Parliaments have forged degrees while the degrees of another 250 Parliamentarians are probably forged as well (they have failed to produce the necessary documentation before the Higher Education Commission in defiance of the orders of the Supreme Court of Pakistan). They spend crores of rupees to reach these exalted positions and once they have succeeded, the loot and plunder begins, while the poor commit suicides or are forced into crime. Once in power, the Ministers manipulate the laws and taxation systems to earn billions. The huge increases in prices of sugar from Rs 32 per kg to Rs 80 per kg a few years ago is just one of many examples, as the sugar import policies were manipulated to provide a windfall of "profits" to the Cabinet Ministers, many of whom possessed large sugar industries. Under military governments, technocrats are often made Ministers, and the governance is invariably better. This explains the better performance of military regimes than the corrupt democracies that we have experienced. However a military regime is not the answer to our problems. A government of internationally eminent technocrats is what is needed.

4. ROLE OF PRIVATE SECTOR IN R & D FOR KNOWLEDGE ECONOMY

The ability of nations to develop a strong knowledge economy depends critically on their ability to access and absorb external knowledge, in particular knowledge about technology, to adapt it to local conditions and to generate new knowledge for value addition, industrial diversification and competitiveness. Research and Development (R&D) expenditure, both public and private, is essential not only for generation of new knowledge, but for absorption, adaptation and diffusion of external knowledge. R&D directly determines the levels of innovation, national competitiveness and economic growth.

While public R&D expenditure is important for supporting university research in both basic and applied fields, it is the private sector (business) R&D expenditure which is critical for firm level learning and building up absorptive capacities in order to bring about a major economic change. Globally, the share of business R&D expenditure has risen much faster than public R&D expenditure. In 2012, the total global R&D expenditure is estimated at around US$ 1. 4 trillion, of which the share of private companies is 63 percent and the share of government is 37 percent. In most OECD countries, the share of the public R&D expenditure has declined but business R&D spending has been rising. Business R&D accounts for 70 percent of total R&D spending in China, 68 percent in the United States, 75 percent in Korea and Japan and 70 percent in Germany. Pakistan's R&D expenditure, 0.64 percent of GDP, is very low compared to India's 0.8 percent, China's 1.6 percent and South Korea's 3.4 percent of much larger GDPs. While in India and China the share of the business R&D has been rising, in Pakistan the share of business R&D is estimated at less than 10 percent of total R&D expenditure and has remained stagnant for many years. In Pakistan, about 60 percent of the public R&D expenditure is spent on funding defense research and the rest is spent on funding research at universities and R&D organisations. There is no expenditure allocated in Pakistan for development, i.e. conversion of research results into products and processes. In China and South Korea, about 80 percent of R&D expenditure is spent on development. Moreover, unlike most developed and East Asian countries, public policy in Pakistan, has not stimulated private R&D through incentives such as tax allowance, tax credits or innovation grants. Contract R&D between industry and university is very limited due to absence of incentives and bridging institutions such as incubators and technology parks. Legal instruments similar to US Bayh-Dole Act, which protect the intellectual property of inventors as a result of public funding, are also missing.

Trans National Companies (TNCs) are an important source of business R&D for developing countries. Innovative firms in developing countries seek alliances with multinational firms to gain access to their R&D, technology, management and marketing capabilities. India and China are major recipients of R&D from TNCs. In Pakistan the government has not negotiated technology transfer with TNCs or encouraged them to establish R&D facilities.

The international network of researchers is another major source of knowledge transfer to developing countries. Taiwan's computer industry and India's IT industry were greatly helped by Diaspora networks. In Pakistan, Diaspora networks have also not been tapped for technology entrepreneurship.

Almost all East Asian countries including Japan, South Korea, Singapore and Taiwan have focused on stimulating business R&D expenditure in selected industries to gain competitive advantage. Chris Freeman (1997) argues that Japan's rapid economic growth after World War II was based on building technology capability of private firms through promotion of contract research in public R&D institutions. This led to increase in private R&D expenditure. The relative concentration of business R&D in a few selected civil technologies provided the necessary competitive advantage to Japanese industry in knowledge intensive sectors such as transport goods and electronics. Private firms in South Korea, Taiwan and Singapore have followed a similar learning strategy to innovate. Public policy encouraged firms to license foreign technology through Original Equipment Manufacturing (OEM). Under OEM firms from developing countries produce products under contract with a TNC. The OEM strategies stimulated firm-based learning and helped firms achieve their own design and engineering capability. This was made possible due to increasing investment in human resource development, training of a critical number of top scientists, technicians and engineers and attracting diaspora to return. Moreover, East Asian governments encouraged firms to innovate and to sell products under their Own Brand Name (OBN).

Public policy has an important role to promote business innovation through direct and indirect policy instruments. There are excellent examples of East Asian countries including China for stimulating business R&D. China introduced its economic and organisational reforms in late 70s. The public S&T and R&D organisations were subjected to three pillars of reforms: i, reform of funding system, ii, improving R&D management and iii, strengthening linkages. The public financial support to the institutions was reduced to force institutions seek other sources of funding either through contract research or by providing consultancy services. Applied research was encouraged through incentives such as licensing of technology developed by institutions, establishing manufacturing operations onsite or creating technology based spinoffs. The government established semi-government bridging institutions between public research institutions, such as engineering centers, technology markets, industrial parks and incubation centers to strengthen linkages between public research institutes and manufacturing organisations.

Industrial and social development needs in most developed and East Asian countries are defined by a long-term vision. A coordinated economic vision with an equity based development strategy needs to be supported by a committed leadership and a transparent bureaucracy selected and promoted on merit. The implementation of the vision requires complete synergy between different ministries at the federal and regional levels. Industrial policy, although considered irrelevant in the market economy, remains relevant for developing countries. Its focus has to shift from protection to enhancing competition, increasing investment for training of high quality scientists, engineers and technicians and most importantly promotion of a learning culture in firms for innovation.

While Public R&D expenditure for supporting university research in both basic and applied fields and for digital infrastructure is important for creative activities and improving teaching quality, the business R&D expenditure is critical for firm level learning and building up absorptive capacities for technical change. Globally, the share of business R&D expenditure has risen much faster than public R&D expenditure. In 2012, the total global R&D is estimated at around US$ 1. 4 trillion, out of this the share of private companies is 63 percent and the share of government is 37 percent. In most OECD countries, the share of the public R&D expenditure has declined but business R&D spending has been rising. Business R&D accounts for 70 percent of total R&D spending in China, 68 percent in the United States, 75 percent in Korea and Japan and 70 percent in Germany

Pakistan's R&D expenditure, 0.3 percent of GDP is very low compared to India's 0.8 percent, China's 1.6 percent and South Korea's 3.4 percent of much larger GDPs. Whereas in India and China the share of the business R&D has been rising, in Pakistan the share of business R&D is estimated at less than 10 percent of total R&D expenditure and has remained stagnant for many years. In Pakistan, 60 percent of the public R&D expenditure is spent on funding defense research and the rest is spent on funding research at universities and R&D organisations. There is no expenditure allocated for development, i.e. conversion of research results in products and processes. In China and South Korea, 80 percent of R&D expenditure is spent on development. Unlike most developed and East Asian countries, in Pakistan, public policy has not stimulated private R&D through incentives such as tax allowance, tax credits or innovation grants. Contract R&D between industry and university is limited due to absence of incentives and bridging institutions such as incubators and technology parks. Legal instruments, similar to US Bayh-Dole Act, which protects the intellectual property of inventors as a result of public funding are also missing.

5. THE ROAD MAP

If Pakistan is to emerge from the shackles of foreign debt, poverty and hunger, it needs to unleash the tremendous creative talents of its youth. Our real wealth lies concealed in the 90 million young below the age of 19 that constitute some 54 percent of our population. This is a huge demographic advantage if we can tap into this vast reservoir of creativity and employ it to migrate from our present low value added agricultural economy to a high value added knowledge economy.

In this scenario, how do we make science, technology and innovation the cornerstones of a "knowledge economy"? In order to build a knowledge economy, Pakistan must invest in developing high quality "knowledge workers" instead of investing simply in infra-structure. Nations are not built by investing in roads, bridges, dams and power houses but by unleashing the creative potential of the masses through developing high quality education systems. Pakistan carried out an extensive "Foresight" type exercise under my leadership to determine how the country could rid itself of the poverty trap and transition to a knowledge economy. This was done under a Cabinet decision of 2004. A 320 page document laying down very clearly a 15 year road map (broken into 3 five year periods) for Pakistan entitled "Technology Based Vision and Strategy for Pakistan's Socio-economic Development" was approved by the Cabinet in August 2007. The specific projects to be undertaken in various key sectors (agriculture, engineering, information technology, telecommunications, electronics, chemicals, pharmaceuticals, textiles, etc.) were identified along with their costs, and benefits to be gained. I was ably helped in this task by late Dr A. R. Kamal, Dr S. T. K. Naim, senior staff members of Pakistan Institute of Development Economics, subject experts in Pakistan and abroad, representatives of industry and the private sector as well as representatives of the provincial and federal ministries.

The document contained specific recommendations for each sector. Space does not permit their inclusion here. The general recommendations approved by the Cabinet were:

(1) To provide incentives to promote private sector R&D for business development including access to Venture capital funds, techno-parks and legal/financial services including professional business plan development to encourage new start-up companies. A key reason for the success of the West is that most of the research and development is carried out by the private sector. This makes it focused, need oriented and dramatically increases possibilities of commercialisation. In Pakistan most of the R & D is carried out in government institutions, which is usually not commercialisable.

(2) Provide Matching Grants to Private Sector for technology upgrading and skills development and offer incentives for private sector industrial R & D (Korea, China, Malaysia models).

(3) To formulate a clear national Technology and Innovation Policy that links Foreign Direct Investment to knowledge transfer in all development projects and addresses the issue of global competitiveness.

(4) Establish an organisation for Technology Assessment and Forecasting (TAF) for carrying out regular Technology Foresight studies.

(5) Improve quality of Technical Training Institutes, with built-in International Accreditation in order to guarantee the high quality of output.

(6) To have strong Networking between various public and private sector institutions in order to achieve common goals. This would involve government funding of collaborative R&D projects of national importance.

(7) To carry out complete restructuring of S&T organisations so that the brightest scientists, engineers are employed on contract basis with excellent market based salaries with clear targets, complete autonomy and full accountability with regular performance assessment.

(8) To establish world class Metrology, Standards, Technology, Quality (MSTQ) infrastructure so that the quality of our industrial products compulsorily meets international standards.

(9) To create critical mass of professionals (scientists/engineers) and technically trained manpower that meets international yardsticks (about 2500 highly qualified professionals involved in R & D per million population)

(10) To provide economical access to world class ICT infrastructure through rapid expansion of broad band services

(11) Create a revolving “Innovation Fund” of Rs. 5 billion to support indigenous technology development in public and private sector

(12) To promote high-tech manufacturing in private sector with foreign collaboration, since that is the key to transitioning to a knowledge economy. This should include granting a “pioneering” status to high tech industries with 15 year tax holidays.

(13) To increase the number of students being sent abroad for Masters and PhD to at least 2000 per year in order to provide high quality manpower in carefully identified priority areas for our universities and research centres.

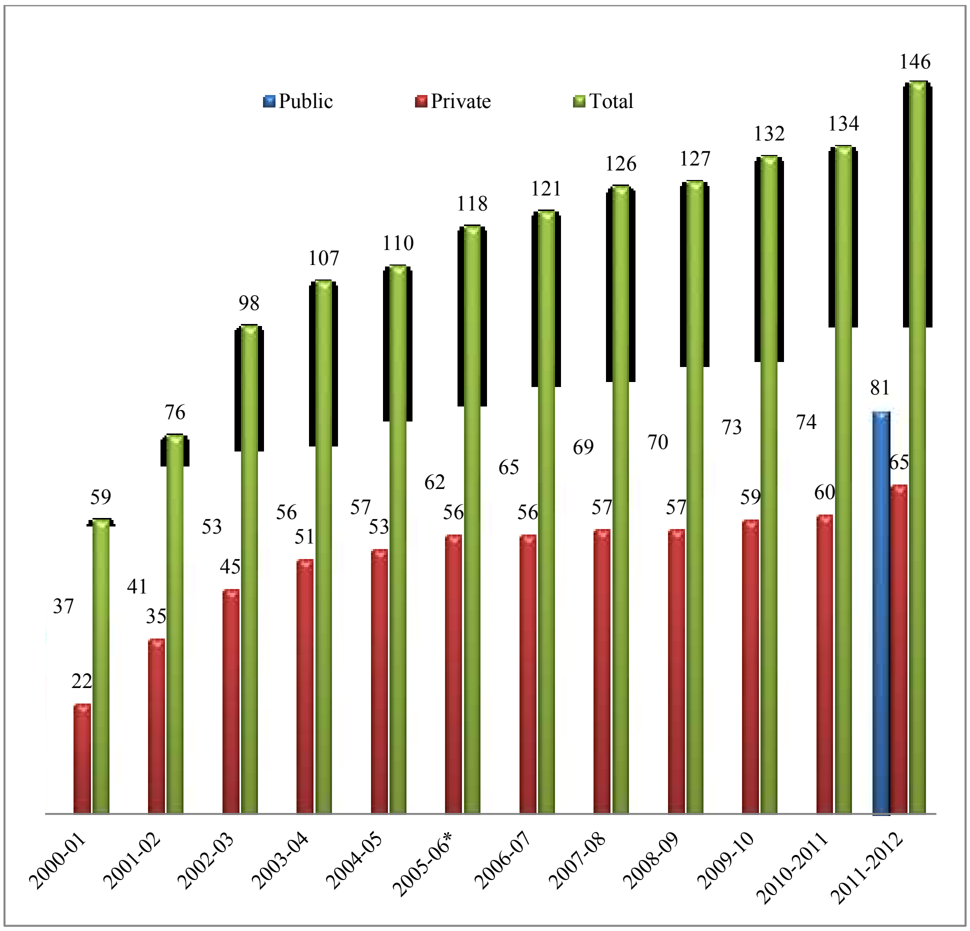
(14) To allocate at least 2.0 percent GNP for S&T programmes with 15 percent of public S&T budget to support skill and technology development in private firms.

A National Inter-Ministerial Committee was constituted by the Cabinet comprising relevant Ministries to implement the recommendations but alas it lies gathering dust.

6. ROLE OF HIGHER EDUCATION IN KNOWLEDGE ECONOMY: PAKISTAN’S PROGRESS

As the Federal Minister of Science and Technology in 2001, I persuaded the government to increase the development budget for science by about 6000 percent. The abolishing of the University Grants Commission and the establishment of the Higher Education Commission in 2002 as a powerful new national body on higher education that was headed by a person with the status of a Federal Minister and which reported directly to the Prime Minister of Pakistan marked a new chapter in the history of higher education in Pakistan. Later in 2002 when I was made the founding Chairman/Federal Minister of Higher Education Commission, I managed to have the development budget for higher education increased also by some 2400 percent. The allocation of substantially increased funds allowed us to undertake programs to uplift the higher education sector. These programs boosted research in universities and they can be broadly categorised as those related to access, quality, research/relevance and governance issues.

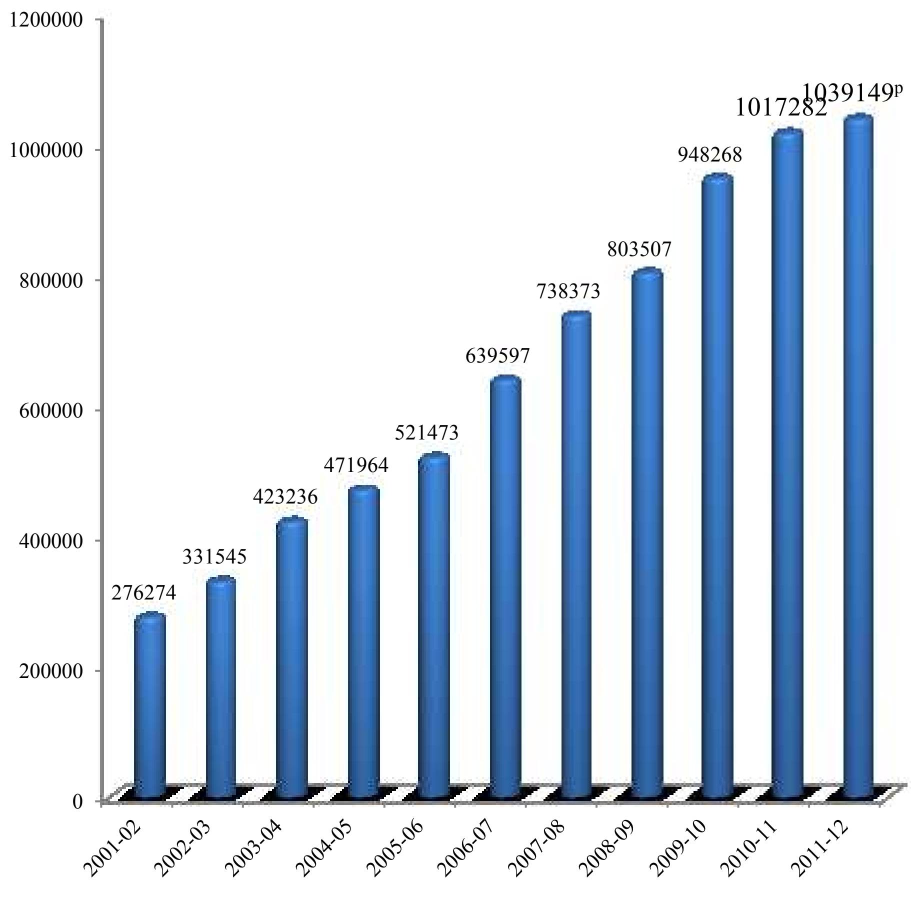
Growth in Universities in Pakistan



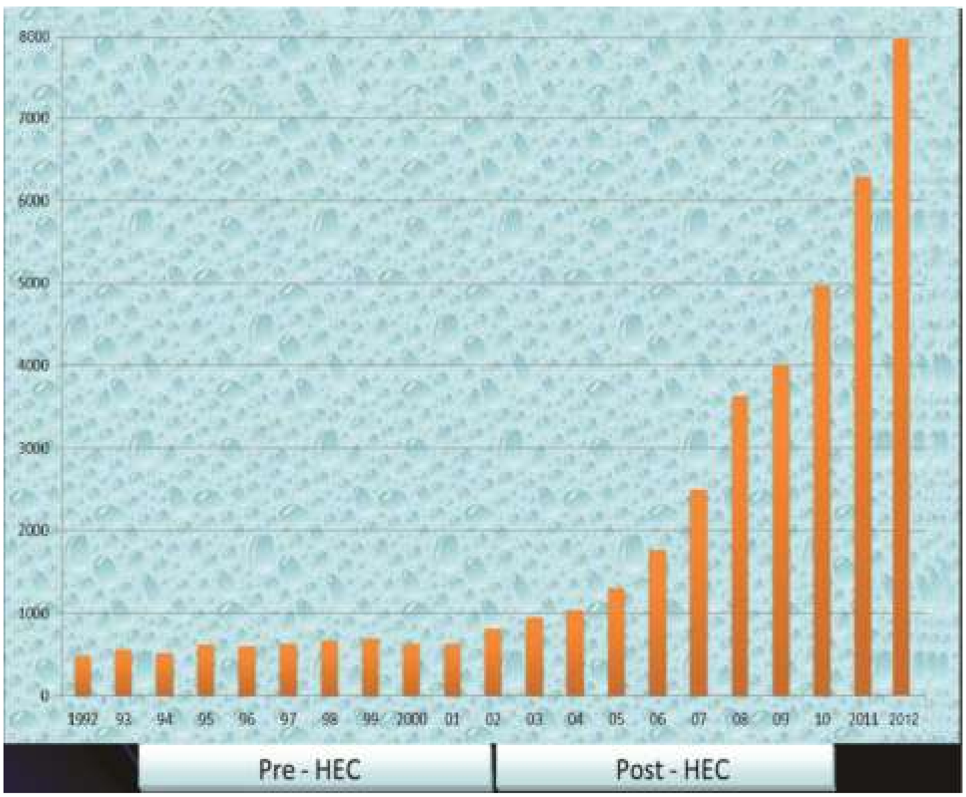
There were only 59 universities and degree awarding institutes in Pakistan in the year 2000. These grew to 127 such institutions by 2008, to 137 institutions by 2010 and to 157 institutions by 2014. University enrolment grew three-fold, rising from only 276,000 in 2002 to about 900,000 students by 2010 and to 1.3 million by 2014. The access to higher education grew from about 2.3 percent of the age group 17-23 in the year

2003 to 6.5 percent by the year 2010. A number of steps were taken to improve the quality of education and make education relevant to national needs. The most significant of these related to the programmes to develop a strong faculty. The fact that in the year 2003 more than 75 percent of the faculty members in Pakistani universities did not even have a PhD pointed to the poor state of affairs at the time. Therefore about 11,000 scholarships were awarded to the brightest students of which some 5,000 scholarships were to obtain PhD degrees at top universities of the world. The remainder were for local PhD level scholarships as well as for sandwich PhD programmes whereby a part of the time of the locally registered PhD student was spent in a leading foreign university.

Higher Education Enrolment in Pakistan

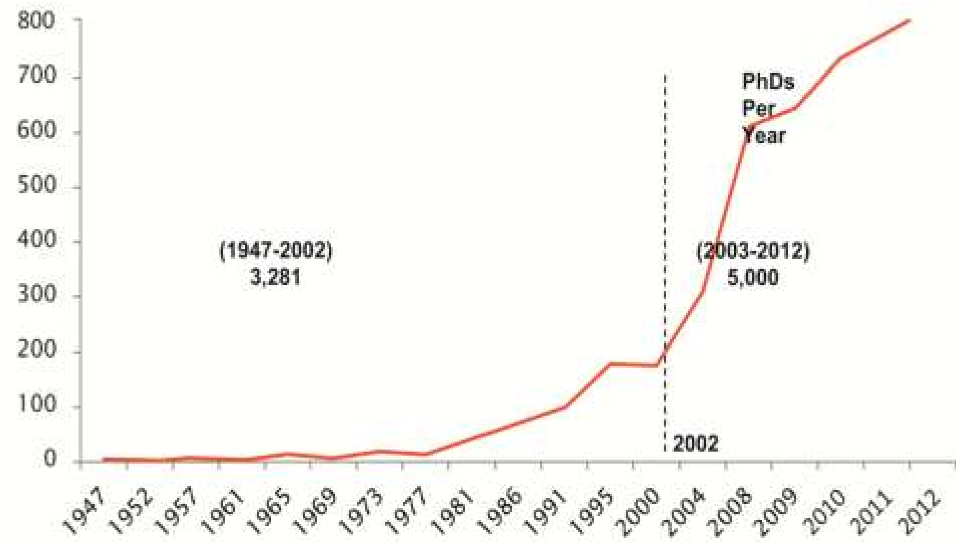


To attract the brightest students passing out of high school to opt for careers in education and research, a new contractual system of “tenure track” appointments of faculty members with international review of productivity was enforced under which the salaries of the faculty members were raised to several times of those of Federal Ministers in the government! The first evaluation of such faculty members was to be done after 3 years by an international panel of experts in technologically advanced countries while the second such evaluation was to be done after 6 years before permanency of tenure was granted after positive peer review on both occasions. In order to ensure that appointments in universities were only made to appropriately qualified persons, new rules were enforced under which persons could not be appointed as Assistant Professors without a PhD. Minimum eligibility criteria for appointments as Associate Professors and full Professors were also toughened so that only those active in high quality research could go up the promotion ladder. Students returning with PhD degrees from abroad were given the opportunity of applying for research grants of up to $ 100,000 one year before their date of return, so that by the time they returned, the peer review process of their research grant application would have been completed and they would be able to settle down with sizeable research funds at their disposal, even if they joined a weaker university with little facilities.



To strengthen the faculty, several new programmes were launched to attract those qualified faculty members working in advanced countries to return to Pakistan at lucrative salaries and with liberal research funding. Some 600 such persons came to Pakistan under these programmes, about half of them permanently and the other half on assignments for one or two terms. Tax rates for all faculty members in public and private universities were reduced from 35 percent to only 5 percent thereby giving a boost to their take-home pay. The foreign faculty members were clustered in various institutions to create the critical mass necessary for excellence in research to thrive. For instance about 40 foreign faculty members (mostly non-Pakistanis from Europe) were appointed in the Centre for Mathematics at the Government College University in Lahore resulting in the emergence of a good mathematics institution. All curricula were revised and modernised in consultation with subject experts and industry order to increase employment and improve quality. A system of internal and external peer review was introduced in all universities and Quality Assurance cells set up in every public sector university, the performance of which was monitored by the Higher Education Commission.

Year-wise Increase in PhD Output of Pakistani Universities



The libraries in universities prior to the year 2002 were in a very poor shape with hardly half a dozen of the latest international journals being subscribed to by any of them. The improvement in the IT infra-structure led to the establishment of a nation-wide digital library under the auspices of the Pakistan Education Research Network (PERN) with some 25,000 international journals and 60,000 text books from 220 international publishers. International Network for Availability of Scientific Publications (INASP) based in Oxford played an important role in negotiating special deals with various publishers. Nation-wide video-conferencing facilities were established in various universities with lectures being delivered interactively from technologically advanced countries on a daily basis.

These and other such measures led to a sudden surge in university rankings. During the 55 year period between1947 to 2002, not a single university could be ranked among the top 400 of the world in international university rankings. By 2008, however several Pakistani universities achieved this yardstick, with NUST (Islamabad) at 273 in the world, UET (Lahore) at 281 in the world and Karachi University (in natural sciences) at 223 in the world. Others included Quaid-i-Azam University (Islamabad) and Mehran Engineering University (Hyderabad). The research publications in journals with ISI impact factors went through an amazing increase from only about 500 per year in the year 2000 to 6,250 per year by 2011, almost equaling those from India if the output is compared on a per million population basis. They continue to in rise by about 20 percent each year. Similarly the citations in the Science Citation Index increased by a 1000 percent in the same period. Many programmes were undertaken to promote university-industry linkages including the establishment of Offices of Commercialisation and Technology Parks in universities and provision of services of patent lawyers and funding for obtaining international patents.

The programmes of the Higher Education Commission were regularly subjected to external review by eminent foreign experts. A USAID team of educationists visited Pakistan a number of times and travelled the length and breadth of the country, talking to teachers, students and administrators in the universities and examining the data critically. I reproduce here sections of the USAID report published in 2008 that resulted from the year-long review:

> *"One of the most striking aspects of HEC since its inception is the emphasis on excellence and high quality in every sphere of its activities. Expectations were set high from the outset. Quality goal targets were set as international standards and expectations. Faculty promotions, publications, PhD dissertations, research grants, and many of the HEC programs were subject to these standards including evaluation by external peer reviewers. — In keeping with its focus on quality, the attitude of the leadership of the HEC was that "quality is much more important than quantity".* Unquote.

A review of the Higher Education system of Pakistan was carried out by Prof. Michael Rode, Chairman of the United Nations Commission on Science, Technology and Development, and Professor at the University of Innsbruck in Austria who visited Pakistan on a number of occasions. He wrote in 2008, and I quote:

> *"Around the world when we discuss the status of higher education in different countries, there is unanimity of opinion that the developing country that has made the most rapid progress internationally in recent years is Pakistan. In no other country has the higher education sector seen such spectacular positive developments as that in Pakistan during the last six years. —After the formation of the Higher Education Commission, a silent revolution occurred and probably the best digital library in the world was set up in Pakistan—Such a nation-wide access to the latest literature is not even available in Europe or USA today, and Pakistan demonstrated that given honest, dedicated and dynamic leadership as provided by Prof. Dr Atta-ur-Rahman and his eminent colleagues led by Dr Sohail Naqvi, it was possible to achieve the almost impossible. Most universities in Pakistan are today equipped with video-conferencing facilities and lectures are delivered regularly by professors from top universities in Europe, USA etc and listened to by students in Sindh, Balochistan and other provinces in real-time and in a fully interactive manner, so that face to face questions can be asked across the world—Pakistan has become the first in the world to introduce a nation-wide international lecturing programme*. (http://dildilpakistan.wordpress.com/tag/dr-atta-ur-rehman/)." Unquote.

The progress made in Pakistan during the short period between 2000 to 2008 rang alarm bells in India. On 23rd July 2006, an article was published in the leading daily Indian newspaper Hindustan Times, entitled "Pak Threat to Indian Science". It was reported that Prof. C. N. R. Rao (Chairman of the Indian Prime Minister's Scientific Advisory Council) had made a detailed presentation to the Indian Prime Minister Mr. Manmohan Singh about the rapid strides that Pakistan was making in the higher education sector after the establishment of the Higher Education Commission in October 2002 and my appointment as its first Chairman. The article began with the sentence ""Pakistan may soon join China in giving India serious competition in science." (http://www.highbeam.com/doc/1P3-1082216661.html), Neha Mehta, "Pak Threat to Indian Science", *Hindustan Times*, 23 July 2006).

Three independent and authoritative reports, praising the outstanding performance of HEC, were published by USAID, the World Bank and the British Council. Pakistan won several international awards for the revolutionary changes in the higher education sector brought about under the leadership of the author. The Austrian Government conferred its high civil award "Grosse Goldene Ehrenzeischen am Bande" (2007) on the author for transforming the Higher Education sector in Pakistan. The TWAS (Academy of Sciences for the Developing World, Italy) Award for Institutional Development was conferred on the author in October 2009.

7. SENSIBLE GOVERNMENT POLICIES FOR A KNOWLEDGE ECONOMY: THE IT/TELECOM EXAMPLE

Information technology has transformed the world into a global village. It has opened up huge new opportunities for the developing world to leap frog and progress rapidly through new avenues that have opened up in education, trade, industry and scientific research. In Pakistan a real beginning in this field started in the year 2000 after a decade of stagnation. During the period March 2000-2002, a 6000 percent increase was given to the development budget of the Ministry of Science and Technology, and 310 projects were launched at a cost of Rs 25 billion in various fields of information technology, telecommunications and science. The IT policy was approved by the Cabinet within six months in an effort ably led by Mr. Salman Ansari. We then set about rapidly expanding the IT sector. The dramatic progress made by Pakistan in the IT/telecom sector during 2000-2002 is presented below:

- The mobile telecommunication sector was given a huge boost. The rates of phone calls from mobile phones were drastically reduced. UFone, was launched and rates of calls from mobile telephone rates were slashed. Previously both the person making the calls and those receiving the calls had to pay call charges. There was therefore a reluctance of most people, particularly those belonging to the lower middle class, to own mobile telephones as they did not want to pay for calls made by others. Following the excellent advice of the Adviser to the Ministry, Mr. Salman Ansari, the Calling Party Pays (CPP) regime was introduced so that persons receiving calls did not pay any charges. This led to an explosive growth of the mobile telephone sector. There were only about 225,000 mobile phones in Pakistan in January 2001. There was a 500 percent increase in the subsequent 18 months as compared to the previous 11 years, reaching 1.2 million by August 2002—the number has now crossed the 100 million mark, making this by far the hottest growing sector of our economy. It has had far reaching impact on the livelihoods of millions.

- Pakistan's Communication Satellite PAKSAT —1 was placed in space by early 2003, thereby securing the strategically important orbital slot in space at 38º East.
- Internet access was rapidly increased from only 29 cities August 2000 to over a thousand cities, towns and villages by 2002, and fibre was laid across the country, increasing penetration from 40 cities to 400 towns and cities.
- The total bandwidth was increased from 32 MB/s in 2000 to 610 MB/s by the end of 2002.
- The rates of bandwidth were reduced from a ridiculous $ 87,000 for 2 MB/s to $ 3500 by the end of 2002, making us the cheapest in the region.
- The number of internet users was increased from only 130,000 in August 2000 to 4 million users by the end of 2002—the exponential growth continued in subsequent years.
- Seven new IT university campuses were established in Lahore, Abbotabad, Baluchistan and Sind, including COMSATS, FAST, Virtual University and provincial universities. IT and computer science departments were established in 34 universities. Over 1000 scholarships were given to IT students for study in Pakistan and abroad.
- Endowments of over Rs 1 billion were created for various universities to promote IT and 25,000 school teachers were trained with support from Intel.
- The Pakistan Educational Research Network (PERN) project connected 56 public sector universities and it became the platform of the HEC digital library providing free access to 60,000 text books and 25,000 international journals in all public sector universities—a huge reservoir of knowledge.
- Software Technology parks were setup at Lahore, Karachi, Peshawar and Islamabad. To promote software exports 15 years tax exemption was given that led to a rapid increase in exports that are presently estimated at $ 800 million, as compared to only $ 30 million in 2001.
- The procedures of Pakistan Telecommunication Authority were simplified so that the average time for approving or rejecting applications was reduced from the previous 360 days to 7 days, thereby curbing corruption.
- Projects amounting to Rs 208 million launched in the four provinces and AJK for computerisation of government departments as part of E-Government initiatives.
- The spectacular progress made in Pakistan in a short two year period in the IT and mobile telecom sectors under my charge as Federal Minister of S&T illustrates the huge potential for progress, given a visionary and honest government.

8. IMPORTANCE OF ENGINEERING EDUCATION IN A KNOWLEDGE ECONOMY

Engineering represents the single most important sector vital for national development. Expertise in engineering lies at the heart of all national development strategies as it determines the level of industrial growth as well as self-reliance in defense manufacture. The steel industry, special alloys, engineering goods, manufacture of industrial machinery, automobile manufacture, electronic, household appliances, robotics and computer science, textiles, chemicals and pharmaceuticals, industrial design—indeed every sector of the national economy depends on engineering.

The emphasis on human resource development, with a special emphasis on engineering, has resulted in the growth of a strong middle class in India that today accounts for about 32 percent of its population, which is increasing by about 1 percent each year. In Pakistan our neglect of education over the decades has meant a much smaller middle class, only about 12 percent of our population, which is shrinking due to increasing inflation, growing poverty, mounting debt that has doubled in the last 3 years and rampant corruption. India collaborated with various technologically advanced countries to help establish seven world class engineering institutions, the Indian Institutes of Technology (IITs) in different cities of India.

The extremely poor state of our engineering universities in Pakistan in the year 2000 is reflected from the appalling fact that in the 53 years between1947 to 2000 our nine engineering universities had together produced only about 10 PhDs in all! In comparison IIT Delhi produced 176 PhDs last year while Tsing Hua University in Beijing produces over a thousand PhDs annually. This is truly shameful for Pakistan, a country claiming to be a nuclear state. Indeed in 2003 we did not have a single genuine engineering university. They were, at best, low level colleges labeling themselves as universities.

Realising the importance of engineering education and research we created significant endowments of Rs 100-200 million for every engineering university to promote research. The key to a high quality university is faculty. Good universities are not developed by building beautiful buildings but by training and attracting highly creative and eminent faculty members. Some 11,000 scholarships were awarded, about 5,000 of them to send our brightest students to top universities in USA, Europe, Australia and China. Almost 2,500 of these were in engineering sciences, including IT and computer sciences. The availability of liberal research grants and other such measures resulted in a spectacular increase in international research publications from only 500 per year in the year 2000 to about 4600 per year by 2010, about a 900 percent growth. Pakistan was producing only 200 PhDs annually in 2002, but this increased to 700 PhDs per year by 2010. The PhD output of our engineering universities also grew from a total of 10 PhDs in 55 years (an average of 0.2 PhDs per year between 1947- 2002) to an average of about 14 per year by 2010, a 150 fold growth. By the year 2009, two of our engineering universities were ranked among the top 300 of the world (NUST and UET Lahore). While this represents a promising beginning, our international standing is still dismally low. All our 9 engineering universities have together produced only 131 PhDs in the last 7 years (an average of about 2 PhDs per year per university), a 70 fold lower productivity than that of IIT Delhi.

The rapid advances being made in Pakistan during 2003-2008 under the Higher Education Commission resulted in alarm bells to ring in India. A detailed presentation was made by Prof. C. N. R. Rao (adviser to the Indian government on Science & Technology) to the Indian Prime Minister about the rapid progress being made in Pakistan in the higher education sector (article by Neha Mehta "Pak Threat to Indian Science", http://www.highbeam.com/doc/1P3-1082216661.html). This resulted in far reaching decisions by the Indian government to accelerate the development of its higher education institutions. Over the next 5 years India will establish 29 new universities and 40 new high level institutes. Nine additional IITs will be established so that India will have 16 world class IITs providing state-of-the-art engineering education. In international rankings of Engineering Universities, IIT Bombay and IIT Delhi are already ranked at 47 and 52, respectively in the world while IIT Kanpur, IIT Madras and IIT Kharagpur are also ranked in the top 100.

In 2005 we embarked on an a visionary project to establish several world class engineering universities in collaboration with Germany, France, Italy, Sweden, Austria, China and Korea that would provide world-class engineering education in Pakistan with degrees being awarded by top foreign universities. Each university was to be established in collaboration with a consortium of top foreign universities. Thus 9 top German engineering universities formed a consortium of 9 top German universities to establish the Pak-German University in Lahore. Similar consortia were formed with the other countries to establish universities in Karachi, Islamabad, Sialkot, and later when the security situation improved, in Peshawer and Quetta. An attractive feature of each university was an integrated technology park in which foreign companies such as Siemens and Eriksson had agreed to establish their Research and Development Centres. This would have led to a surge in international patents of new products and processes and a huge increase in high tech exports. Pakistani parents spend about Rs 100 billion each year on sending their children to foreign universities. Besides saving this expenditure, the scheme would have led to significant earnings of foreign exchange due to many foreign students coming to Pakistan for study.

The development schemes to establish four of these foreign engineering universities were approved by ECNEC in February 2008, and classes were scheduled to begin in October 2008. Unfortunately disaster struck. HEC budget was slashed in 2008, scholarships frozen and most development projects, including the establishment of the foreign engineering universities in Pakistan, halted. A wonderful and unique opportunity to provide high quality engineering education from top foreign universities within Pakistan and to make rapid advances in industry and defense was thrown away. When the scholarships of thousands of Pakistani students studying abroad, many in the engineering sciences, were withheld, causing huge misery in 2008, I resigned in protest in October 2008.

Things did not stop there. A notification was issued by the Government on 30th November 2010 shredding HEC into pieces. HEC was almost destroyed. Fortunately the Supreme Court of Pakistan accepted my Appeal and declared the government notification unconstitutional. HEC has fortunately survived this onslaught. It continues to exist and limp along under difficult financial circumstances in a hostile environment.

9. ROLE OF AGRICULTURE SECTOR IN A KNOWLEDGE ECONOMY

Agriculture represents the backbone of our economy. It can serve as a launching pad for transition to a knowledge economy, as it has a huge potential for revenue generation, if agricultural practices are carried out on scientific lines, and use of technology maximised. The four major crops of Pakistan are wheat, rice, cotton and sugar cane. They contribute about 37 percent of the total agricultural income and about 9 percent to the GDP of Pakistan. Because of the wide fluctuations in productivity, the contribution to GDP has been variable, making it imperative to diversify our crops in order to have a stable agricultural income and a predictable GDP. The minor crops in Pakistan include vegetables, fruits, oil seeds and pulses. There is a high growth potential in vegetables, fruits, flowers, livestock and fisheries that can be tapped through proper planning and technological inputs but this potential remains largely untapped because of lack of visionary leadership and proper planning.

Wheat is the most important crop of Pakistan, with the largest acreage. It contributes about 3 percent to the GDP. The national average yield is about 2.7 tons per hectare whereas in Egypt the yields are 6.44 tons per hectare and in European countries such as France, Germany and United Kingdom they are above 7 tons per hectare. We presently produce about Rs 220 billion worth of wheat. If we can boost our yields to match those of Egypt, it can generate another Rs 350 billion, allowing us to systematically pay off the national debt and make available funding for health and education. However the government has been reluctant to invest in research, water reservoirs/dams and extension services so that the country continues to suffer. Some progressive farmers in irrigated areas have been able to obtain yields of 6-8 tons per hectare but they are very much a minority. In rain fed areas the yields are normally between 0.5 tons to 1.3 tons per hectare depending on the region and amount of rainfall. In irrigated areas the yields are normally higher, in the range of 2.5 tons to 3.0 tons per hectare. Improved semi-dwarf cultivars that are available in Pakistan can afford a yield of wheat between 6-8 tons per hectare. It is possible to increase the yields substantially with better extension services, judicious use of fertilisers and pesticides, and greater access of water from storage reservoirs and dams that need to be constructed.

Cotton represents an important fibre crop of Pakistan that generates about Rs 250 billion to the national economy, and contributing about 2 percent to the national GDP. Pakistan is the 4th largest producer of cotton in the world but it is ranked at 10th in the world in terms of yields. The use of plant biotechnology can help to develop better cotton varieties. Bt cotton produces a pesticide internally and safeguards the plant against chewing insects. The yields of Pakistan seed cotton and cotton fibre are both about half those of China. A doubling of cotton yields is doable and it can afford another Rs 250 billion to the national economy.

Pakistan produces about 6.5 million tons of rice each year. Our yields are however very low, being only about 1.7 tons per hectare as compared to 7.4 tons per hectare produced by USA, and 6.59 tons per hectare produced by China. Similarly our yields of maize (about 1.7 tons per hectare) are about a quarter of those obtained in France (8.2 tons per hectare). The yields of sugar cane in Pakistan range from 40 tons per hectare in Punjab to 60 tons per hectare in Sind, dismally low as compared to Egypt (120 tons per hectare).

Pakistan needs to fund biotechnology research programs in order to increase yields. India established a separate Department of Biotechnology in 1986 that supports about 5,000 scientists each year, provides funds to some 4000 postdoctoral students, and its initiatives have led to some 5000 publications. Indian exports of biotechnology based products are expected to reach $ 5 billion in 2012 and exceed $ 50 billion within 15 years. Pakistan needs to tax agricultural income and then invest 30 percent of the tax collected into agricultural research and into the strengthening of extension services.

Pakistan faces tough times ahead as the water shortage will have devastating consequences by 2050 due to global warming. We need to prepare ourselves now for the tough years ahead. Initially the global warming will cause large scale melting of snow clad mountains, leading to huge floods. This water must be captured and stored in dams and water reservoirs so that we are adequately prepared for long periods of draught that will occur in subsequent decades.

10. CONCLUSION

In this fast changing world, the key to progress lies in the abilities of nations to unleash the creative potential of their youth in order to develop strong knowledge economies. It is the nature, quality and efficiency of the interactions between the three major players, universities, industries and government that determine how a knowledge economy evolves. Pakistan, a country with a population of about 190 million, has about 100 million below the age of 19 (about 55 percent). This demographic advantage can be used for socio-economic development if the country focuses its policies on science, technology, innovation and entrepreneurship that create job opportunities for the young in value added sectors.