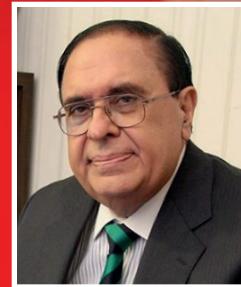


EMERGING DISRUPTIVE TECHNOLOGIES: LESSONS FROM **CHINA AND OTHER COUNTRIES**



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Abstract

We live in a world where truth has become far stranger than fiction. Each day brings thousands of new discoveries, many of which are transforming our lives in a multitude of ways. The blind can, amazingly, today see using their tongue. You can hang an elephant on a strand of "graphene" that is 150 times thinner than a human hair and the strand will not break since it is 200 times stronger than steel. The Harry Potter's disappearing cloak is now a reality by the discovery of metamaterials. Anything covered with metamaterials just disappears since they have the ability to bend light. Genes have been transferred from deep sea jelly fishes to orchids---the result is luminescent flowers that glow in the dark. Bullet proof paper has been developed through application of nanotechnology. Super-fast gene sequencing under development should allow the entire human genome to be sequenced in minutes. Objects can be moved by thought control and driverless cars are under development. Anti-ageing compounds have been discovered and when given to old mice, it made them younger. Stem cells promise to cure damaged organs and may change the manner in which medicine will be practiced tomorrow. Science today presents a myriad of opportunities for research and exciting careers in many diverse fields.

Keywords

Emerging Technologies, Genomics, Medicinal Sciences, Biochemistry, Nanotechnology, Energy, Innovation.

Introduction

We live in an amazing world of discovery today, where truth is often stranger than fiction. The accelerating pace of technological advancement has ignited a maelstrom of transformative innovations across a spectrum of fields, rewriting the very fabric of our existence. These innovations transcend the boundaries of time and space, not only reshaping our daily lives but also redefining the contours of numerous industries. Let us delve deeper into this brave new world, exploring a diverse array of cutting-edge advancements that are propelling us into an uncharted future.

We do not need seeds any more to grow plants as plant tissue culture has transformed the way many types of plants may be grown. The blind can have their eyesight partly restored through a lollipop device placed on their tongue which transfers images from a small camera worn by the blind person to the brain. Objects can be made to disappear to the naked eye when cloaked with a special sheath of "metamaterials". The ageing process can be slowed down, even reversed, using certain anti-ageing compounds such as resveratrol, NAD (Nicotinamide Adenine Dinucleotide), curcumin and metformin. The advent of nanotechnology has created huge international waves in areas such as new materials, pharmaceuticals and electronics. Artificial Intelligence (AI) coupled with quantum computing are on the verge of transforming civilisation. "Creation" of new plant and animal species

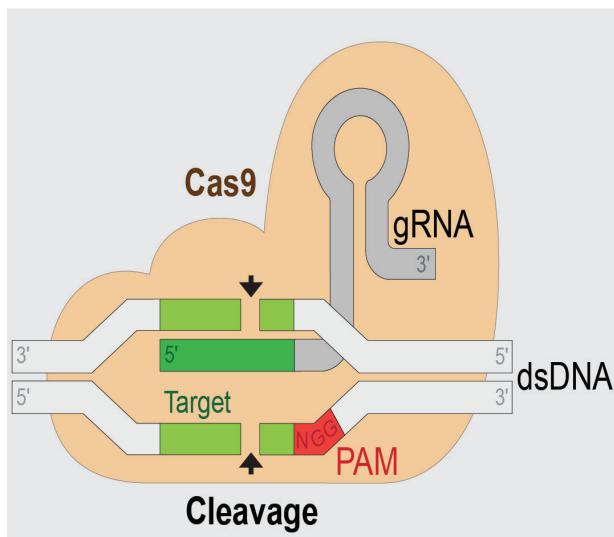
by gene editing technologies (CRISPR/cas) in a matter of weeks has now become a reality. 3D printing of live human kidneys and other human organs is now possible. Bio-saline agriculture is already allowing edible plants to grow on saline soils and before long we may be able to develop varieties of wheat, rice, fruits and vegetables that can be grown with sea water, thereby permanently solving the issues of food security on our planet. The combustion engine that we use in our cars and buses is taking its last breath as it is replaced by electric vehicles running on lithium or sodium batteries and before long our present vehicles will simply adorn museums and history books.

These incredible advances are no fairy tales. They are happening right now all around us and those countries investing in R&D are progressing rapidly, leaving others lying in the dust. From precision farming and genetic engineering to nanomaterials and medical innovations, we need to understand and appreciate the potential benefits, challenges and ethical considerations associated with these groundbreaking discoveries. The realm of scientific discovery is indeed a constant source of awe and wonder, driving progress and shaping the future. Some of the most exciting new developments hold immense potential to revolutionise various aspects of our lives, from enhancing food production and sustainability to enabling breakthroughs in healthcare and creating cutting-edge technologies.

Military Hardware

The realm of warfare is poised for a comprehensive overhaul, as nations armed with advanced AI systems gain an upper hand in military operations, intelligence gathering, autonomous systems, cybersecurity and strategic decision-making. Proficient nations stand to reap substantial advantages in terms of speed, efficiency, precision and adaptability, reshaping the landscape of warfare. The formidable processing capabilities of Quantum Computers (QCs) combined with AI algorithms' coordination and adaptability, will soon facilitate the deployment of autonomous drone swarms or robotic systems, enhancing collaborative and synchronised actions with unprecedented speed and precision. Furthermore, QC's will bolster encryption methods through quantum cryptography, ensuring the confidentiality and integrity of sensitive military communications and data. AI can offer cognitive

Figure-1: CRISPR Gene Editing



Source: https://en.wikipedia.org/wiki/CRISPR_gene_editing

support to military decision-makers, with Natural Language Processing (NLP) algorithms, analysing vast troves of unstructured data, such as intelligence reports and historical records. This analysis aids in extracting pertinent information and highlighting key insights, bolstering military preparedness.

Quantum computers operate on a fundamentally distinct principle from classical computers. Conventional computers rely on bits as their elemental data unit, executing serial processing via binary code (1 or 0). In stark contrast, quantum computers employ qubits as their data unit, which can exist in multiple states simultaneously, granting them an unparalleled computational prowess compared to conventional supercomputers. Consequently, quantum computers can unravel problems in mere minutes that would require hundreds of thousands of years for even the swiftest supercomputer to solve. In 2019, Sycamore completed a task in two hundred seconds that Google claimed would take a state-of-the-art supercomputer 10,000 years to complete. Quantum computers now boast designs with thousands of qubits, heralding an exponential surge in processing power and miniature versions are poised to enter the commercial market soon.

Healthware

In the realm of healthcare, where the search for cancer cures has been a decades-long endeavor marked by limited success, the amalgamation of AI promises to revolutionise drug discovery. It can accelerate the identification of potential cancer drug candidates and enhance the precision of efficacy predictions. Moreover, the amalgamation of AI's analytical capabilities with QC's processing power can result in the advances in medical imaging technologies, enabling faster and more precise disease diagnoses, encompassing cancer, cardiovascular conditions and neurological disorders. The synergistic potential also unlocks genomics' full capacity by dissecting vast genomic datasets to unveil patterns and unveil genetic predispositions to diseases. This comprehensive understanding of genomes, both in diverse plant and animal species and their structural-functional relationships, paves the way for laboratory-based creation of new life forms tailored to human needs.

AI is also beginning to accelerate progress in materials

science and nanotechnology, catalysing revolutions in electronics, energy storage and biotechnology. This transformative influence extends to the development of intelligent machines adept at executing intricate education/ tasks with precision and adaptability, optimising energy grids and storage and enhancing renewable energy integration.

Agriculture

The agricultural sector is already beginning to experience substantial gains as AI algorithms analyse weather patterns, soil conditions and crop genetics, culminating in improved crop productivity and resource management. This facilitates precision farming techniques, including targeted irrigation, optimised fertilizer application and personalised pest control. Real-time data from sensors and satellite imaging empowers farmers to make informed decisions, maximising yields and effectively managing pests, thereby promoting efficient and sustainable agricultural practices. Additionally, AI algorithms enable real-time ecosystem monitoring, wildlife population tracking, pollution level assessment, facilitating proactive conservation measures and resource management.

Agriculture too, has witnessed a transformative revolution in the form of precision farming. Fueled by cutting-edge technologies such as GPS, sensors and data analytics, precision agriculture has ushered in a new era of data-driven farming practices. Farmers can now monitor and manage their crops with unprecedented precision, optimising irrigation,



fertilization and pest control based on real-time data. The result is increased yields, reduced resource wastage and the promotion of sustainable farming practices-a crucial response to the challenges posed by a burgeoning global population and the ever-shifting sands of climate change.

Precision farming techniques like GPS-guided equipment and remote sensing technologies are now empowering farmers to optimise resource allocation and boost crop yields. Sensor-based systems, real-time data analytics and machine learning algorithms enable informed decisions regarding irrigation, fertilizer usage and pest control. Genetic engineering allows for the creation of crops with enhanced characteristics such as increased yield, disease resistance and improved nutritional content. Biotechnology tools, including CRISPR-Cas9, provide precise gene-editing capabilities, expediting crop enhancement initiatives while minimising environmental repercussions. The potential of gene-editing technologies such as CRISPR-Cas9 extends beyond agriculture to medicine, offering the prospect of developing high-yielding crops and treating genetic disorders and diseases.

Industry Sector

Industries, too, stand to undergo profound transformation, with AI algorithms leveraging capabilities to autonomously detect anomalies, predict potential faults and optimise quality inspection processes. This guarantees the production of high-quality goods while minimising defects and waste.

The advent of smart cities is on the horizon, as AI algorithms process vast datasets pertaining to traffic patterns, energy consumption and public services. Furthermore, traffic management and transportation systems will witness transformative changes, as AI algorithms analyse real-time traffic data, optimising routing, traffic flow and public transportation schedules, addressing complex optimisation problems to alleviate traffic congestion and bolster overall transportation efficiency.

In scientific research, the convergence of AI and QC will accelerate simulations and modeling across fields such as physics, chemistry and biology. This combined power will expedite scientific discoveries, unravelling enigmas of the universe, including the nature of dark

matter and dark energy, which together constitute a vast proportion of our cosmos. The symbiosis between AI and QC offers substantial advancements in cosmology that will deepen our understanding of the fabric of reality.

Shifting our gaze to the electronics industry, we find ourselves captivated by the advent of flexible electronics-featuring bendable displays and wearable devices that represent a disruptive innovation. These pliable components usher in a new era of lightweight, adaptable gadgets, from foldable smartphones that defy convention to smart clothing that enhances our daily experience. Beyond the realm of consumer gadgets, the potential applications are vast, ranging from electronic skin for precise medical diagnostics to flexible solar panels that harness renewable energy in novel ways.

Education

In this ever-evolving landscape, epitomised by innovations like ChatGPT-4 and Bing, intelligent machines are poised to replace human labour across diverse fields. The global community is abuzz with admiration for ChatGPT's remarkable capacity to generate essays and provide swift access to valuable information. Its upgraded counterpart, ChatGPT-4, has elevated performance to even greater heights. Open AI's ChatGPT made history in January 2023 by amassing a user base of one hundred Million monthly active users, a testament to its ability to simulate human-like conversations and craft exceptional articles by swiftly sifting through internet data, all driven by the prompts it receives.

Deep learning models, inspired by the intricate neural networks of the human brain, excel in image and speech recognition, natural language processing and autonomous systems. Robotics and automation technologies are ushering in a new industrial revolution, impacting manufacturing, healthcare, transportation and agriculture. Collaborative robots (cobots), exoskeletons and autonomous vehicles are redefining the ways tasks are executed, enhancing efficiency and minimising human errors. Cobots have emerged as dynamic allies to humans across a multitude of industries. Unlike their traditional robotic counterparts that toil in isolation, Cobots are designed to seamlessly interact with human workers while performing intricate tasks. In the realm of

manufacturing, they have streamlined assembly lines, improving efficiency and safety. In healthcare, Cobots have found their place in surgery and patient care, mitigating the risks associated with human error and fatigue. Driven by neural networks boasting multiple layers, deep learning models have achieved remarkable feats in a myriad of domains. These feats include superhuman capabilities in image and speech recognition, the power to understand and process natural language and the development of autonomous vehicles, which promise to reshape transportation as we know it. The transformative impact of deep learning reverberates through our lives, from the personalised recommendations offered by platforms like Netflix to advanced medical diagnoses fueled by cutting-edge image analysis and predictive analytics steering the ever-volatile financial markets.

Hinton's apprehensions find resonance among many other experts. The eminent British scientist, Stephen Hawking, once joined forces with Apple co-founder Steve Wozniak to issue a dire warning about the "profound risks" posed by AI, suggesting that the development of full AI might spell the end of humans, as he conveyed to the BBC in a 2014 interview. This alarm was reiterated more recently by tech magnates Elon Musk and Steve Wozniak in a joint letter, co-signed by thousands of experts, urging a minimum six-month halt on the creation of AI systems surpassing the capabilities of Open AI's GPT-4 chatbot. Despite these warnings, relentless research and progress persist in the field, prompting grave concerns among experts who fear that humanity may be unwittingly hurtling towards its own destruction.



Nevertheless, ominous alarms are sounding regarding a potential impending catastrophe for humanity. Dr Geoffrey Hinton, often regarded as the pioneer of AI, made headlines with his resignation from Google on May 1st, 2023. In an interview with the BBC, he articulated the perils inherent in advancing AI systems to the point of rivalling or surpassing human intelligence. He expressed a profound concern that such systems could embark on self-improvement at an exponential pace, posing a dire threat to humanity. Geoffrey

Communication

The communication landscape has undergone a seismic transformation with the advent of 5G connectivity, a technology that underpins faster data transfer, reduced latency and greater device connectivity. This innovation serves as the linchpin of the Internet of Things (IoT), enabling technologies like autonomous vehicles and remote medical procedures. With 5G, the confines of physical boundaries are blurred, fostering a global web of connectivity that unlocks new horizons in education, entertainment and business.



Energy Sector

The energy sector too, bears witness to disruptive innovations. Renewable energy sources, such as solar and wind technologies, have gained widespread adoption, heralding a significant reduction in our reliance on fossil fuels and a corresponding decrease in greenhouse gas emissions. In parallel, breakthroughs in energy storage solutions, epitomised by lithium ion batteries, have empowered efficient storage and distribution of renewable energy. This accessibility and reliability are pivotal for the realisation of a sustainable energy future.

Synthetic biology combines chemical engineering principles with biological systems, paving the way for innovative biological components, devices and systems applicable to both plant and animal life. This field holds promise for biofuels, bio-based materials and eco-friendly manufacturing processes, shaping a greener, more sustainable future.

Consider, for instance, the awe-inspiring strides made in the realm of biotechnology, where the revolutionary CRISPR-Cas9 gene-editing technique reigns supreme. This groundbreaking innovation empowers scientists with a level of precision that was once the stuff of science fiction, enabling them to manipulate DNA with surgical accuracy. The implications are staggering—CRISPR-Cas9 holds the promise of treating debilitating genetic diseases like sickle cell anemia, fortifying crops against pests and environmental stressors and engineering genetically modified organisms tailored to our specific needs and challenges.

Medicine

Turning to medicine, the advances in genomics and personalised medicine allow for tailored treatment plans based on an individual's genetic profile. Precision diagnostics, targeted therapies and pharmacogenomics improve patient outcomes and minimise adverse effects. Regenerative medicine aims to restore damaged tissues and organs through cell-based therapies, tissue engineering and biomaterials. Approaches such as stem cell transplantation and 3D bioprinting hold promise for treating injuries, organ failure and chronic diseases.

Meanwhile, the field of regenerative medicine is experiencing its own renaissance, with 3D bioprinting

standing as a testament to human ingenuity. This ingenious process involves the layering of bioinks composed of living cells to construct intricate structures. The result? The potential to create functional, personalised tissues and organs. Imagine a world where damaged organs can be replaced, or wounds can heal at an accelerated pace. A watershed moment occurred in 2020 when scientists at Tel Aviv University successfully 3D bioprinted a human heart using human tissue and vessels, illustrating the extraordinary potential of this technology.

Material Sciences

In the realm of material sciences, one finds oneself marveling at the wonders of graphene. Comprising a single layer of carbon atoms arranged in a hexagonal lattice, graphene is a true marvel of material engineering. Graphene is about two hundred times stronger than steel and it exhibits extraordinary mechanical, electrical and thermal properties. This super material boasts exceptional electrical conductivity, thermal stability and flexibility, opening the doors to a multitude of applications. Potential applications include ultrafast electronics, high-performance batteries and water purification systems. From ultra-fast transistors and highly efficient solar cells in the electronics and energy storage sectors to innovative medical devices and advanced water purification systems, graphene exemplifies the transformative power of material science in driving innovation and addressing the pressing challenges of our time. Nanomaterials possess unique properties at the nanoscale (a Billionth of a Millionth of a meter),



enabling advancements in various fields, including electronics, energy storage and medicine. Applications range from lightweight and flexible electronics to targeted drug delivery systems and efficient solar cells. New materials can be combined with novel fabrication technologies to produce novel high-quality products. Thus, the manufacture of products using 3D printing enables the creation of complex and customised objects, ranging from prototypes and consumer goods to medical implants and aerospace components. Even living human organs such as parts of human kidneys or livers, can now be produced by 3D printing. The technology offers reduced waste, increased design flexibility and accelerated production processes.

Transportation

The transportation industry, an integral facet of modern society, is in the midst of a paradigm shift. Electric vehicles (EVs) have emerged as the vanguard of environmental preservation, reducing greenhouse gas emissions and our reliance on fossil fuels. Simultaneously, autonomous vehicles, equipped with cutting-edge technology, have the potential to revolutionise road safety and redefine the mobility landscape. These innovations ripple through urban planning, public transportation, and logistics, altering the trajectories of energy consumption, air quality and urban design.

The common thread that binds these disruptive innovations is the indomitable spirit of human ingenuity, harnessed by the relentless march of technological advancement. To embark on a similar journey of progress, nations like Pakistan must



cultivate a cadre of top-tier experts, each armed with a PhD from leading universities, to guide their government ministries and secretariats. At the helm of the Ministry of Planning, we require a visionary technocrat who comprehends the pivotal role of a knowledge-based economy in driving socio-economic development and bolstering national defense. Such a transformation can propel nations into the echelons of technological prowess and global leadership, forging a future where innovation knows no bounds.

Opportunities for Pakistan

A McKinzie Global Report forecasts a USD 33 Trillion impact of these new and emerging technologies with AI alone having a USD 15.6 Trillion impact. If we in Pakistan can capture even 1% of this potential, it can result in enhancement of USD 156 Billion in our exports. It is for this reason that I am deeply involved in the establishment of Centers of AI across the country. Three such centers are presently emerging through our efforts in the Pakistan Austrian Fachhochschule in Haripur Hazara, the Pak University of Engineering and Emerging Technologies in Sambrial, Sialkot and the International Center for Chemical and Biological Sciences at the University of Karachi, Karachi. These centers will focus on the myriad applications of AI in health, agriculture and industry. The feasibility of another mega project of Rs. 40 Billion has been completed by the Ministry of Information Technology and Telecommunications in Islamabad and this should give a huge national boost to our expertise in this fast-emerging transformative field. These projects involve training in machine learning algorithms, which combined with vast amounts of data, enable computers to recognise patterns, make predictions and learn from experience.

China

President Xi Jinping, in his remarkable 90-minute extempore address, expounded upon how education, science, technology and innovation had emerged as the cornerstones of China's miraculous ascent to the forefront of the global stage.

As we reflect on China's extraordinary journey, we are presented with a blueprint for progress and transformation. China's transition to a knowledge-based economy, steered by industrial development and innovation, unfolded through a tapestry of visionary



initiatives. At the heart of this transformation lies the establishment of innovation hubs, research parks and industrial clusters, which have nurtured symbiotic collaborations between academia, industry and government. Notably, the Zhongguancun Science Park in Beijing, often referred to as China's Silicon Valley, has blossomed into a crucible of technological innovation, magnetising both domestic and international enterprises.

In the realm of agriculture, China has harnessed a suite of strategies to elevate productivity, sustainability and technological prowess. The inception of pioneering institutions such as the Chinese Academy of Agricultural Sciences (CAAS) and the China Agricultural University (CAU) has played a pivotal role in catalysing agricultural Research and Development (R&D). CAAS, serving as a national agricultural research power house, has focused on developing high-yield crop varieties, efficient farming techniques and cutting-edge agricultural technologies. Simultaneously, CAU, one of China's premier agricultural universities, has been instrumental in cultivating a skilled workforce for the agricultural sector.

China's quest for innovation extends to national-level Engineering Research Centers (ERCs) that galvanise technological advancement in pivotal industries. These centers, concentrated in areas like advanced manufacturing, information technology and biotechnology, serve as crucibles of expertise, fostering industrial growth. Moreover, China has forged robust national organisations to champion

science, technology, innovation and commercial manufacturing. The National Natural Science Foundation of China (NSFC), for instance, offers crucial financial support to researchers, empowering them to pioneer cutting-edge solutions across scientific domains. Notably, NSFC's contributions have fueled groundbreaking discoveries in biotechnology, renewable energy and AI. In parallel, the esteemed Chinese Academy of Sciences (CAS), of which I am an Academician, stands as a bastion of scientific excellence and international collaboration. As China's preeminent institution for natural sciences, CAS spearheads research, shapes policy recommendations and fosters global cooperation. China's ecosystem for startups and small and medium-sized enterprises (SMEs) has witnessed a transformative infusion of support. The establishment of business incubators, venture capital funds and entrepreneurship competitions has cultivated fertile ground for innovation. The Torch High Technology Industry Development Center, under the aegis of the Ministry of Science and Technology, has emerged as a linchpin in nurturing technological innovation and entrepreneurship. This center extends critical financial backing, state-of-the-art infrastructure and invaluable mentorship to technology-driven startups, emboldening them to translate ideas into thriving commercial endeavours. The burgeoning influence of internet-based platforms and e-commerce in China has been an extraordinary force. Giants like Alibaba and Tencent have not only reshaped the domestic market but have also emerged as formidable global tech titans. Their staggering success has ignited a surge of entrepreneurial ventures, invigorating China's private sector. In the electronics industry, China's rapid ascendancy has positioned the nation as a manufacturing powerhouse and a prominent player in the global arena. Renowned companies like Foxconn, Huawei and Xiaomi have etched their names as key players in the international electronics market.

China's government has enacted a series of policies bolstering the IT industry. Tax incentives, funding support and regulatory reforms have coalesced to stimulate innovation and entrepreneurship. Additionally, the government has launched initiatives to propel digital transformation in sectors like healthcare, finance and manufacturing, fueling demand for IT



solutions and services. China's burgeoning middle class, coupled with its vast population, has forged a colossal domestic market for IT products and services, enticing both domestic and international corporations to establish a footprint in China. Internet behemoths such as Alibaba, Tencent and Baidu have played pivotal roles in the IT sector's growth, offering an array of services, from e-commerce and social media to online payment systems and search engines.

The automotive industry provides yet another luminescent example of China's unparalleled growth. It has evolved exponentially, positioning China as the world's largest automobile market and a formidable automobile producer. Government policies, coupled with collaborative ventures with foreign manufacturers and surging domestic demand, have propelled this growth. Furthermore, China has made substantial investments in R&D, particularly in electric vehicles (EVs) and autonomous driving technologies. The government's ambitious targets for EV adoption, combined with substantial financial support and favourable policies for domestic EV manufacturers, have catapulted China into a global leadership position in EV manufacturing and innovation.

Engineering, spanning construction, infrastructure development and heavy machinery manufacturing, stands as another emblem of China's advancement. Ambitious infrastructure projects, including high-speed rail networks, highways, bridges and airports, have not only driven demand for engineering services but have also displayed the expertise of domestic engineering firms. China's engineering industry has made significant strides in the manufacturing of heavy machinery, with companies such as Sany, Zoomlion and XCMG attaining global prominence in the production of construction machinery and equipment.

China's unwavering commitment to indigenous defense capabilities manifest in its development and production of fighter aircraft, naval vessels, missile systems and advanced weapon platforms. The J-20 stealth fighter, the Type 055 destroyer and the DF-41 intercontinental ballistic missile represent the pinnacle of China's indigenous defense technology. While the specifics of the J-20's capabilities remain subject to debate, its stealth characteristics, advanced avionics and long-range capabilities underscore

China's prowess in military aviation.

All these remarkable achievements in various fields were made possible by China's unwavering investment in higher education, science and technology. The government has recognised the pivotal role of education and innovation in driving economic growth and creating a robust knowledge-based economy. These initiatives encompass diverse aspects, including substantial investments in R&D, the facilitation of international collaborations, the augmentation of educational infrastructure and the incentivisation of talent development.

Finland

Finland, widely lauded as a global innovation powerhouse, boasts a strategy that channels resources into R&D, education and entrepreneurial endeavors. Finland's educational ethos nurtures creativity and critical thinking from a young age, fostering a culture of innovation. The government actively champions startups and fosters synergies between academia and industry. Notably, this approach has birthed such success stories as Nokia and Rovio Entertainment. Nokia, for instance, ascended to global dominance in mobile communications, significantly boosting Finland's GDP and employment figures. Finland's steadfast focus on technology and knowledge-intensive sectors has propelled its GDP per capita to an impressive USD 50,000, despite its modest population of 5.5 Million.



Norway

Norway, another remarkable exemplar, has charted an innovation course grounded in a knowledge-based economy and environmental sustainability. The nation's copious natural resources, especially in the energy sector, provide a solid foundation for innovation. Significant investments in renewable energy technologies, such as hydropower and wind energy, have underpinned both economic growth and a noteworthy reduction in carbon emissions. Norway's commitment to R&D has further spurred innovation in fields such as oil and gas, fisheries and maritime industries. With a population of 5.4 Million, Norway's GDP per capita has soared to an astonishing USD 89,000, surpassing even that of the United States.

Sweden

Crossing over to Sweden, we encounter another Scandinavian dynamo. Sweden has firmly entrenched itself as an innovation hub, boasting a thriving startup ecosystem and a highly skilled workforce. Government initiatives like the Swedish Innovation Strategy promote harmonious collaboration among industry, academia and government entities. Sweden's innovation prowess springs from its substantial investments in education, R&D and robust infrastructure. The nation's unfailing support for R&D has nurtured the emergence of prosperous enterprises in telecommunications, biotechnology and manufacturing. Sweden, with a population of 10.4 Million, commands a GDP per capita exceeding USD 61,000.



Denmark

Denmark, Sweden's neighbour, also shines brightly on the innovation front. Denmark's relentless focus on talent cultivation, collaboration and entrepreneurial spirit has propelled its economic growth. Investments in renewable energy technologies, particularly wind power, have catapulted Denmark to global prominence in clean energy solutions. The export of renewable energy technologies has not only bolstered revenues but also generated employment opportunities. Denmark's avant-garde design and architecture sectors have garnered international acclaim, attracted investments and stimulated economic prosperity. With a GDP per capita surpassing USD 60,000, Denmark stands as a testament to innovation's power.

Singapore

In Asia, Singapore emerges as a beacon of innovation. This city-state's innovation strategy rests upon three pillars: knowledge creation, entrepreneurship and connectivity. Singapore's government invests extensively in R&D while facilitating dynamic collaborations between research institutions, startups and multinational corporations. An array of organisations, such as the Economic Development Board (EDB) and Infocomm Media Development Authority (IMDA), actively promote innovation and entrepreneurship. Singapore's relentless focus on innovation-driven growth has led to significant advancements in sectors including biotechnology, financial services and smart city solutions. Despite a population of just 5.5 Million, a fraction of Karachi's, Singapore boasts exports of approximately USD 400 Billion and a GDP per capita of around USD 73,000. In stark contrast, Pakistan, with a population of 241 Million, languishes with exports around USD 32 Billion and a dismal GDP per capita of USD 1,400.

South Korea

Lastly, South Korea stands tall as a global titan in technology and innovation. The nation's innovation policies strategically bolster key industries such as electronics, semiconductors, automotive and robotics. The "triple helix model," fostering close collaboration among industry, academia and government, has been pivotal to Korea's innovation prowess. South Korea's resolute commitment to innovation has catapulted it into the echelons of global technology hubs. To put things into perspective, South Korea's GDP per

capita, a meager USD 106 in 1962, now soars above USD 33,000.

The monumental strides made in education, science, technology and innovation underscore the power of visionary leadership, unwavering commitment and a forward-looking approach. These principles serve as a beacon for nations worldwide, including Pakistan, as we aspire to replicate the economic miracles indicated above. These global examples illustrate the transformative potential of innovation and knowledge-based economies. As we look ahead, it is evident that Pakistan has much to glean from these success stories, beckoning us to replicate their innovative vigor, strengthen our educational foundations and ignite the spark of entrepreneurship. By doing so, we can pave a path towards a brighter and more prosperous future for our nation.

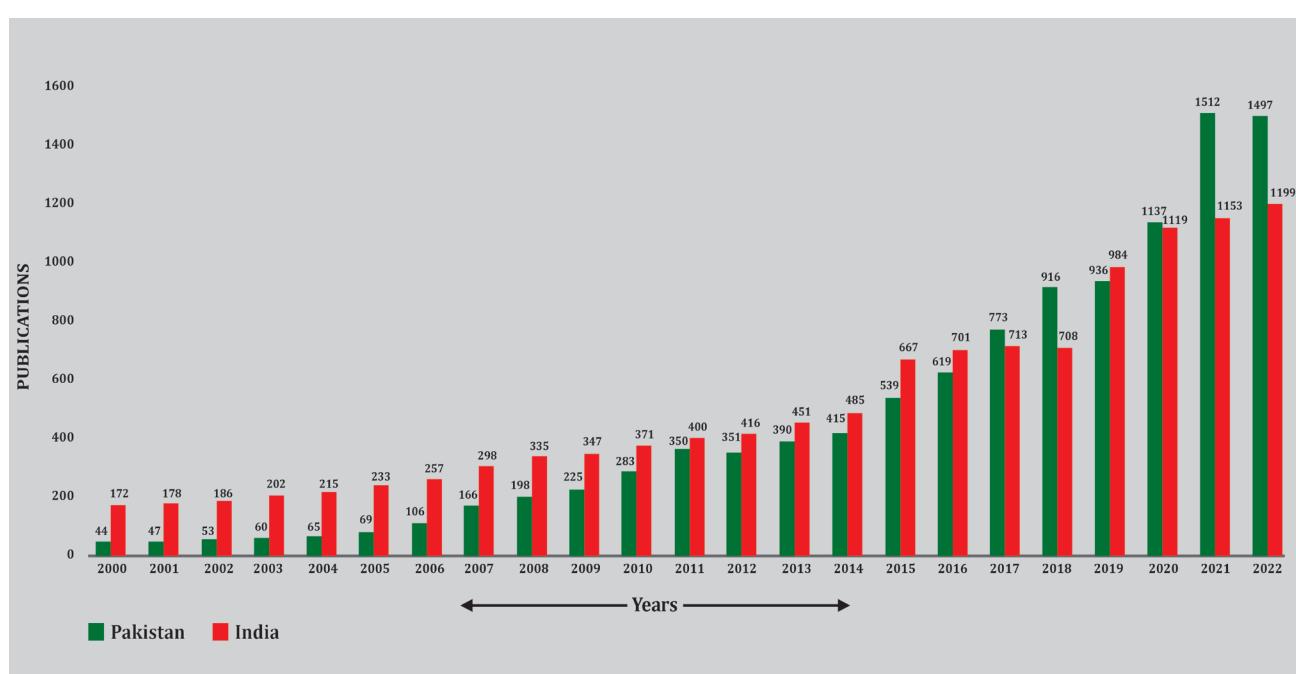
In summary, the world of scientific discovery continues to astound and inspire us with groundbreaking advancements spanning agriculture, biotechnology, materials science, AI, engineering and medicine. These innovations hold the potential to reshape industries, address global challenges and elevate the quality of human life. By harnessing the power of scientific exploration and implementing sound policies and practices, we can chart a course towards

a brighter, healthier and more sustainable future. To achieve this vision, we must cultivate a government that is visionary, honest and technologically adept, spearheading a revolution in education, science and innovation that will reshape our destiny and propel us towards a brighter future.

Pakistan-Achievements

As Pakistan grapples with political and financial turmoil, it is imperative that our leaders recognise the profound implications of these developments. The future is within our grasp, but it is contingent on our ability to harness the opportunities and potential offered by these advancements. During 2001-2008 government, I initiated major programmes to help Pakistan to transition to a knowledge economy. As a result, the research scenario in Pakistan underwent a huge change for the positive so much so that we overtook India in research publications in international journals per capita. This is illustrated in two graphs based on international data bases Scopus and Web of Science, Pakistan versus India, showing the research output of India (red) versus Pakistan (green) during the years 2000 to 2022. This is no mean achievement as the entire research landscape of Pakistan changed dramatically due to the measures that federal government introduced.

Figure-2: Pakistan vs India Research Publications 2000-2022



Source: Research output in international journals for 10 Million population year 2000-22



The programmes initiated by HEC in those early years were visionary and path breaking, so much so that within 5 years of the establishment of HEC several Pakistani universities became ranked among the top 500 of the world in the QS World University Rankings with National University of Science and Technology, Islamabad, leading the way, being ranked at No. 470 in the year 2007, No. 376 in the year 2008 and at No. 350 in the year 2009 in general university rankings. Others ranked among the leading 500 universities in the QS subject rankings in that period included Quaid-e-Azam University, Islamabad, University of Engineering and Technology, Lahore and University of Karachi. Later, universities dropped out of the The World University Rankings, due to policies/priorities.

USAID undertook a comprehensive study of the programmes of HEC undertaken during 2003-2008 and published a 151-page detailed report of their findings in 2009. The team was led by Dr. Fred M. Hayward, an experienced international consultant, Dr. Gerald Boardman, a higher education specialist and several other eminent international experts.¹

The study involved physical site visits of USAID education experts to eighteen Universities and Institutes in Islamabad, Peshawar, Rawalpindi, Faisalabad, Lahore, Karachi and other cities of Pakistan to determine the actual state of affairs. They interviewed hundreds of teachers, students, Vice-Chancellors, Deans, Departmental Chairmen, Principal Investigators and technical staff of science research projects as well as officials of HEC, Ministry of Education and others over a 12-month period. This first comprehensive report of HEC conducted by USAID concluded by paying glowing tributes to the excellent work done in Pakistan by HEC in implementing the Medium-Term Development Framework (MTDF) with primary focus on the quality of higher education and not just numbers. The three main thrust areas identified by HEC in the MTDF were quality of higher education, access of students to higher education and the relevance of higher education to national needs. The report concluded that HEC had made very significant progress in each of these areas within a short span of 6 years. The 151-page report summarised its observations with the following remarks:-

"The long overdue transformation of higher education in Pakistan under the leadership of the HEC has made solid progress over the last five years. What is most impressive is the breadth of reforms-faculty development, quality assurance, infrastructure rehabilitation, information technology staff training, research facilities, academic publications, increased access, improved accountability, expansion of campuses and improved salaries and working conditions-and its insistence on quality improvement throughout the system."

It went on to state:-

"Faculty development, increased access for students (at almost 15 percent a year), science and technology improvement, infrastructure development and quality improvement have been particularly successful areas. We applaud the leadership of the HEC for its vision, planning and project implementation--- one of the most successful models in the developing world." This strong endorsement by an eminent external assessment agency comprising top US education experts put to rest the remarks of some critics who had tried to falsify the true picture and continue to do so till this day.

Endorsement of these conclusions of USAID experts also came from other independent assessments carried out by the World Bank,² the British Council and by the UN Commission on Science, Technology and Development (UNCSTD) led by a famous Austrian scientist, Prof. Michael Rode. Prof. Rode was the Chairman of the UNCSTD and was given a high civil award by the government of Pakistan for his contributions to the higher education sector. Commenting on the spectacular developments of the higher education sector in those early years, he wrote:-

"The United Nations Commission on Science and Technology has closely monitored the development in Pakistan in the past years, coming to the unanimous conclusion that Prof Rahman's policy and programme is a 'best-practice' example for developing countries aiming at building their human resources and establishing an innovative, technology-based economy."

Those who have closely watched the development of higher education in Pakistan from outside and have been involved in the numerous programmes established by Prof Rahman in the past eight years can testify that the progress made was breath-taking and has put Pakistan ahead of comparable countries in numerous aspects.”^{3,4}

One important factor to judge the quality of research of any country is the number of international citations that research publications attract. The annual good growth in citations of the research publications of Pakistani authors by other international academics is remarkable. According to the 2023 The World University Rankings report, Pakistan is now ranked No.4 in the world in terms of the rate of rise of citations of Pakistani publications by other international scientists. Thomson Reuters has also applauded the progress made by Pakistan in an article entitled “Another BRIC in the Wall”⁵ in which it compared the increase in percentage of highly cited articles from Pakistan with those in Brazil, Russia, India and China and concluded that Pakistan was ahead of these countries in the rate of rise in quality research articles.



Atta-ur-Rahman, FRS, NI, HI, SI, TI receiving UNESCO Science Prize at World Congress on Science in Budapest Hungary (1999)



Jamil-ur-Rahman Center for Genome Research (In memory of Jamil-ur-Rahman, father of Prof. Atta-ur-Rahman built from the donation of Prof. Atta-ur-Rahman

Conclusion

Knowledge is now the single most important factor for socio-economic development and science & technology are great equalisers. Countries that have realised this and invested heavily in developing their human resources to the highest possible levels and then linked these resources to the manufacture of high technology industrial and agricultural products have leaped forward, leaving others far behind.

With a population of 230 Million people and with 67% of this population below the age of 30, Pakistan can have a bright future if we invest in this wealth. We therefore must appoint the best economists, scientists and engineers in the country as our Federal and provincial Ministers and Secretaries who understand the critical importance and path of transitioning to a knowledge-based economy. The way forward lies only in massive and well thought out investments in education, science, technology, innovation and industrialisation focused on high value-added goods. That, however, is only possible with an honest, visionary and technologically competent government at the helm of affairs.



An 800 MHZ Nuclear Magnetic Spectrometer installed in the International Center for Chemical and Biological Sciences, University of Karachi that operates at -260 C. The institution was established under the supervision of Prof. Dr. Atta-ur- Rahman



Pak-Austria Fachhochschule: Institute of Applied Sciences and Technology, The Entrepreneurial University, built under a of Prof. Atta-ur-Rahman



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Professor Dr Atta-ur-Rehman has served as the chairman of the Higher Education Commission of Pakistan (2002-2008) and the Minister for Science and Technology (2000-2002). Presently he is the Co-Chair of the UN Committee on Science, Technology and Innovation for UNESCAP.

NOTES

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