Towards a Knowledge Economy-National Innovation and Technology System of Pakistan

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List of Acronyms

ADD	Agency for Defense Development
ADF	Augmented Dickey Fuller
AEDB	Alternative Energy Development Board
AI	Artificial Intelligence
AIDP	Auto Industry Development Program
AIDS	Acquired Immunodeficiency Syndrome
API	Active Pharmaceutical Ingredients
APMA	Association of Pakistan Motorcycle Assemblers
ARDE	Armament Research and Development Establishment
ARE	Alternative Renewable Energy
ARPANET	Advanced Research Projects Agency Network
ASIP	Access to Scientific Instrumentation Program
BECO	Batala Engineering Company
BIPP	Shahid Javed Burki Institute of Public Policy at NetSol
BRI	Belt and Road Initiative
BRIC	Brazil, Russia, India, China,
CEO	Chief Executive Officer
CJ	Civilian Jeep
CM	Chief Minister
CNG	Compressed Natural Gas
CNIPA	China National Intellectual Property Administration
COO	Chief Operating Officer
CPEC	China Pakistan Economic Corridor
CPPS	Cyber Physical Production Systems

CPS	Cyber Physical Systems
CSAF	Cooperation Assistance Fund for Technology Transfer
DARPA	Director of Defense Advanced Research Projects Agency
DESTO	Defense Science and Technology Organization
DITS	District Innovation and Technology System
DITP	District Innovation and Technology Plan
DNA	Deoxyribonucleic Acid
DPP	Digital Pakistan Policy
DSL	Digital Subscriber Lines
DUI	Doing, Using, Interacting
EDF	Export Development Fund
EIS	European Innovation Scorecard
EODB	Ease of Doing Business
EPO	European Patent Office
FC	Forman Christian
FDI	Foreign Direct Investment
FTE	Full Time Equivalent
GB	Gilgit Baltistan
GCI	Global Competitiveness Index
GDP	Gross Domestic Product
GERD	Gross domestic expenditure on R&D
GHG	Greenhouse Gas Emissions
GII	Global Innovation Index
GNP	Global Production Networks
GPN	Global Production Network

GT	Grand Trunk Road
GVC	Global Value Chains
HCI	Heavy Chemical Industry
HDI	Human Development Index
HEC	Higher Education Commission
HIT	Heavy Industries Taxila
HIV	Human Immunodeficiency Viruses
HR	Human Resources
HRst	Human Resources in Science and Technology
THE	High Tech Exports
IBM	International Business Machines Corporation
ICT	Information and Communication Technology
IGCEP	Indicative Generation Capacity Expansion Plan
IMF	International Monetary Fund
IP	Intellectual Property
IPO	Intellectual Property Organization
IPR	Intellectual Property Rights
IR	Industrial Revolution
IRRI	International Rice Research Institute
IS	Innovation System
ISF	Innovation System Framework
ISO	International Organization for Standardization
IT	Information Technology
ITS	Innovation Technology System
JPO	Japan Patent Office
KANUPP	Karachi Nuclear Power Plant
KERC	Knowledge Economy Resource Centre

KIAST	Korea Advanced Institute of Science and Technology
KIPO	Korean Intellectual Property Office
KIST	Korea Institute of Science and Technology
KPK	Khyber Pakhtunkhwa
KRL	Khan Research Laboratories
KS&EW	Karachi Shipyard and Engineering Works
LASS	Latin American Structuralist School
LKPC	Lahore Knowledge Park Company
LUMS	Lahore University of Management Sciences
MIT	Massachusetts Institute of Technology
MOST	Ministry of Science and Technology
MRI	Magnetic Resonance Imaging
MW	MegaWatt
NAVTTC	National Vocational and Technical Training Commission
NBER	National Bureau of Economic Research
NBS	National Business Systems
NCS	National Commission for Science
NCST	National Commission for Science and Technology
NED	Nadirshaw Edulji Dinshaw
NEPRA	National Electric Power Regulatory Authority's
NEQS	National Environmental Quality Standards
NES	National Entrepreneurship System
NESCOM	National Engineering and Scientific Commission
NIAB	Nuclear Institute for Agriculture and Biology
NIC	National Incubation Centers
NIS	National Innovation System

NITS	National Innovation and Technology System
NLS	National Learning Systems
NPT	Treaty on the Non-Proliferation of Nuclear Weapons
NRPU	National Research Program for Universities
NRTC	National Radio and Telecom Corporation
NSTC	National Science and Technology Council
NTB	National Training Bureau
NTDC	National Transmission and Dispatch Company
OECD	Organization for Economic Cooperation and Development
OEM	Original Equipment Manufacturing
OLS	Ordinary Least Squares
ORA	Outstanding Research Awards
ORIC	Offices of Research, Innovation and Commercialization
OSRD	Office of Scientific Research and Development
OSTI	Office of Science and Technology Innovation
P&DDS	Planning & Development Departments
PAC	Pakistan Aeronautical Complex
PACO	Pakistan Automobile Corporation
PAEC	Pakistan Atomic Energy Commission
PARR	Pakistan Atomic Research Reactor
PASTIC	Pakistan Scientific and Technological Information Centre
PC	Planning Commission
PCSIR	Pakistan Council for Scientific and Industrial Research

PDSP	Power Sector Development Program
PHEC	Punjab Higher Education Commission
PIA	Pakistan International Airlines
PIDC	Pakistan Industrial Development Corporation
PINSTECH	Pakistan Institute for Nuclear Science and Technology
PITP	Provincial Innovation and Technology Plan
PITS	Provincial Innovation and Technology System
PKR	Pakistani Rupee
POF	Pakistan Ordnance Factory
PPCR	Pakistan Program for Collaborative Research
PPP	Public Private Partnerships
PSQCA	PakistanStandard Quality Control Authority
PT	Total number of Patents
QS	Quacquarelli Symonds
R&D	Research and Development
ROI	Return on Investment
RRI	Rice Research Institute
RTO	Research Technology Organizations
S&T	Science and Technology
SAGE	Semi-Automatic Ground Environment
SATUMA	Surveillance and Target Unmanned Aircraft
SDG	Sustainable Development Goals
SDPI	Sustainable Development Policy Institute
SEZ	Special Economic Zones
SIPO	State Intellectual Property Office
SIPRI	Stockholm International Peace Research Institute

SKD	Semi-Knocked Down
SME	Small and Medium Enterprises
SMEDA	Small and Medium Enterprise Development Authority
SRGP	Start-up Research Grant Program
STEM	Science, Technology, Engineering, and Mathematics
STI	Science, Technology and Innovation
STJ	Scientific and Technical Journal
SUPARCO	Space and Upper Atmosphere Research Commission
TAVTA	Technical and Vocational Training Authority
TBS	Tariff Based Scheme
TDF	Technology Development Fund
TEVTA	Technical Education and Vocational Training Authority
TH	Triple Helix
TIFF	Technology and Innovation Financing Framework
TISC	Technology and Innovation Support Centres
TRIMS	Trade Related Investment Measures
TS	Time Series
TTC	Toyota Tsusho Corporation
UC	University of California
UET	University of Engineering and Technology
UH	Utility Helicopter
UITSP	University Industry Technology Support Program
UK	United Kingdom
UN	United Nations
UNAIDS	Joint United Nations Programme on HIV/AIDS

UNDP	United Nations Development Programme
US	United States
USA	United States of America
USD	United States Dollar
USPTO	United States Patent and Trademark Office
VC	Venture Capital
VDTC	Vendor Development and Technical Cell
VTOL	Vertical Take Off and Landing
WEF	World Economic Forum
WHO	World Health Organization
WIPO	World Intellectual Property Organization

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The publication of this book will not have been possible without the devoted assistance of many colleagues, friends and partners and well-wishers of the Shahid Javed Burki Institute of Public Policy (BIPP) who very generously provided their comments and perspectives on the subject and enlightened the authors with their valuable insights. A great debt of gratitude is owed to Professor Dr. Shahid Imtiaz for meticulously reviewing the original manuscript and Professor Dr. Suleman Aziz Lodhi, management sciences, innovation and technology expert and our colleague Dr. Ejaz Sandhu who were readily available to coordinate and guide, both technically and managerially, the process of completing this seminal and pioneering work. In producing the second print, the authors were fortunate to benefit from the razor-edge feedback and critique of Mr. Babar Yaqoob Fateh Muhammad who meticulously reviewed the manuscript and provided immensely valuable comments to set-right the editorial mistakes and better organize the material both on substance and format. The untiring and dedicated facilitation and commitment of Ms. Atr-un-Nisa and Ms. Tabinda Naz in research and data verification and designing, formatting and infographics and final proof reading was indeed commendable while Mr. Firas Shams, Ms. Aiman Adnan and Ms. Zahra Suleman deserve special mention for providing the editorial assistance. The logistics support of the BIPP team led by Mr. Awais Khalid must also be acknowledged duly and that of Dr. Sajjad Haider for facilitating the publication of this book.

Though a great effort has been put in to avoid omissions or errors of fact, the authors take full responsibility of deficits and slippages, if any.

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Authors' Note

The launch ceremony of the book "Towards a Knowledge Economy – National Innovation and Technology System of Pakistan" was hosted by the Punjab Higher Education Commission on 12 January 2024 and presided over by its Chairman Dr. Shahid Munir. The event was very well attended and graced by eminent members of academia including the Vice Chancellors of several notable universities, research scholars, experts of high professional caliber, senior civil servants, the private sector representative and renowned politicians. It was indeed very heartening to note the wide and enthusiastic acclamation by the participants of the pioneer research work of the authors to prescribe a comprehensive framework for embracing the knowledge economy as the only viable option to realize country's national development goals. An all-inclusive effort bolstered by political commitment at the highest level and close nexus of academia, industry and government are indeed *sine qua non* for the purpose, especially in view of the rapidity and intensity of technological advancement in a highly competitive world.

Launch ceremony at PHEC, 12 January 2024

The subsequent series of launch events and seminars on the book especially in the Centre for Public Policy and Governance of FC College University, Government Graduate College for Women and IT University, Lahore added immense credibility to the substance and contents of the book, notably the conceptual evolution of Innovation System Framework and its applicability to Pakistan; the historical saga and vicissitudes of S&T landscape of Pakistan; analysis of what works and what does not work and the technology-led success stories e.g., Chinese experience, South Korean Innovation and Technology System, MIT Model etc. The participants, in particular, appreciated the robust way forward and implementation framework prescribed by the authors for establishing National Innovation and Technology System as the kernel for moving towards Knowledge

Economy paradigm. They also endorsed the idea of a compelling vision "Developing Innovative Pakistan", Charter of Innovation, a three tiered vertically synergized and horizontally linked operational structure for transformative shift to knowledge economy and the accompanying sustainable financial mechanism.

Govt. Graduate College (Women) **IT University, Lahore** **FC College University**



The authors have also received a number of laudatory comments and remarks from senior government officials, Chambers of Commerce and Industry, private businesses and the scholars and professors engaged in academic and research work. They have fervently advocated the need to harness the intellectual capital of the country, capitalize on science and scientific discoveries, emerging technologies and innovations and applied research to change the existing sub-optimal consumption and production patterns and economic growth models to address the enormity of development challenges that the country faces. The consensus seems to be to pursue knowledge and technology-led growth to achieve sustainable human development for bequeathing a better Pakistan to posterity.

Inspired by this complimentary and appreciative response from the professionals and the policy makers, the authors have decided to issue the second print of the book to further advance the scholastic discourse and policy debate on the Knowledge Economy- a subject of vital significance for the country on which, to a large extent, hinges the future destiny of Pakistan. This version also takes care of the typos, better organization of the contents and the editorial mistakes identified in the first version. The authors hope that this endeavor will stimulate a serious and earnest policy debate at all levels and across all institutions including government, private sector and university and higher learning knowledge generating systems to lead to action oriented, time-bound and adequately funded institutional, policy and programmatic frameworks for moving towards a knowledge economy.

Shahid Najam, Athar Mansoor, Rehmat Ullah
24 May 2024

Foreword

Pakistan's economic history, a subject I have studied for several decades and written about in several books and articles, establishes that political stability is an important contributor to economic growth. That apart, economic historians have also argued that technological and organizational innovation is responsible for accelerating economic growth and modernization.

Economists believe that the state of any given economy depends a great deal on history and historical experience. They have a phrase for this: they call it "path dependence." Where Pakistan is today, reflects where it was yesterday and the day before. Most of the economic and social problems the country faces today and those that would prevent it from realizing its potential can be traced to history. There is a need for today's policy-makers to inter alia, break from the past and adopt the policies and strategies that would realize the country's economic potential and lay the solid foundations for moving the economy and society to a higher technological plane. When technological development as a serious subject is internalized by those responsible for making public policy, it affects all aspects of a government's involvement. Science, technology and innovation (STI) play important roles in economic development and modernizing society. These also bring about greater integration in the global system. The state needs to be deeply involved in achieving these objectives. These include, first, the development of several public sector institutions that, in the case of Pakistan, were set up at various times to undertake STI work. Second, there is also the need to rationalize the institutional structure that oversees technological development in the private sector. Third, there is the need to invest in improving both the reach of education and its quality. At the moment, there are several institutions that are involved in the government's efforts in this area. Several of these

have overlapping responsibilities creating considerable inconsistency and confusion among the members of the community of investors. The focus of technological change has to be on individuals, firms and government departments with academia and research institutions playing a key role in accelerating growth and modernizing society.

Pakistan, though suffered with dearth of S&T resources at its inception, in the first 20 years after independence in 1947, it achieved highest growth rate in South Asia and its overall exports were more than Indonesia, Malaysia, Philippines, Thailand and Turkey combined in 1965 (World Bank Report 2002).[1] During the time of the 1960s, the growth of manufacturing sector was recorded at 9.9 % with the number of initiatives which created a good trend for the smooth growth.[2] It was essentially government's commitment at the highest level to embark on 5 years plan and lay sound S&T foundations in the country to sustain the growth. Even countries like Indonesia and, in particular, South Korea benefited from the technical assistance of Pakistani planning authorities in formulating five-year plans during this period.[3] While Pakistan witnessed decadence in the S&T landscape post-1960s onwards due to the multiplicity of reasons including the nationalization policy of the 1970s which stalled technology demand, adoption, and diffusion, a number of countries in South Asia notably China, South Korea, Singapore and Taiwan managed to transform their economies by adopting technology-led economic development model. China has become a major source of both technological development as well as technological transfers. It achieved this status by ensuring, inter alia, that the massive flow of FDI into China especially from the USA is linked to transfer of technology in the major development sectors e.g., manufacture of automobiles, aircrafts, telecom equipment etc. At the same time, the Chinese invested great amounts of resources in strengthening the R&D capability of their university system and educating and training its own people. Once again, the United States was the preferred destination. According to the Open Doors Report, 2024 on International Exchange released on November 15, 2022 more than 682,000 Chinese students were enrolled in American institutions in 2022-23. Most

of them were studying in institutions with established reputations for having specialized in the teaching of STEM.[4] Beijing's China-Pakistan Economic Corridor investment program offers an exceptional opportunity for Pakistan where the transfer of technology could become an important component of the projects under the long term CPEC plan. China is, in particular, committed to developing SEZs across Pakistan which could become a potent vehicle for technology transfer, catch up and sustainable development.

For Pakistan, however, to fully harness the economic and technological development potential, the country must establish a conducive policy and institutional framework and mechanism to be able to pursue a knowledge and technology-led development paradigm.

This book "Towards a Knowledge Economy: National Innovation and Technology System for Pakistan" produced under the aegis of the Shahid Javed Burki Institute of Public Policy which I established some years ago, presents an inventive attempt to spell out the contours and blueprint for the policy-makers to put in place a robust National Innovation System for accelerating the pace of innovation and technological development in Pakistan and for ultimate transformation of the economic structure to the knowledge based economy.

The book's major emphasis and vigor in its arguments is that Pakistan needs to pursue with commitment and consistency a compelling vision of "Developing Innovative Pakistan" that drives, integrates, and directs the entire nation into a single agenda of knowledge economy. The focus should be on three intertwined components i.e., wealth creation; poverty alleviation; and sustainable growth. The strong political ownership, activation of the university and research system in R&D and active engagement of the private sector are the conditions precedent for the purpose. The accompanying prerequisites are adequate resource allocation and investment in S&T, basic education for quality human resources, technology adoption, and diffusion especially, commercialization of available technologies through startups and large-

scale enterprises. The authors strongly advocate a major departure from the traditional linear model of technology development and espousal of a dynamic S&T advancements framework to guide the methods of innovation, areas of innovation, and speed of innovation. The value-add of the book is that the authors, as development practitioners, go much beyond the theoretical analysis and based on evidence, logic and successful practices, propose a concrete way forward and intervention model for instituting a potently functional national innovation and technology system.

The policy and decision-makers in the government, academia and private sector are the major target audience of this book. They may find it intellectually stimulating and its recipe viably implementable to lay the foundation of a knowledge based economy in Pakistan. This would not only enable the country to catch up but also fully utilize its potential as a robust, competitive and sustainable economy in a highly globalized world.

Shahid Javed Burki
Former Vice President of the World Bank, Caretaker Finance Minister of Pakistan (1996-97) And Chairman Shahid Javed Burki Institute of Public Policy, Lahore Pakistan
May, 2024

Notes

1 World Bank Report 2002
2 Pakistan Journal of Humanities and Social Sciences January – March 2019, Volume 7, No. 1, Pages 77 – 91
3 Dawn 13 Dec 2013
4 opendoorsdata.org https://opendoorsdata.org › Calls to Action

Preface

The global political and economic order is constantly evolving and is witnessing an unprecedented pace of change in the wake of massive impact of climate change on the environmental integrity of the planet and the post- Covid-19 pandemic repercussions on the lifestyle of the people and the way they live and earn their livelihood. The conduct of trade, business, economic and commercial activities and delivery of public services has undergone a transformation of extraordinary proportion with the concomitant challenges in almost all walks of human existence e.g., economic, political, social, cultural, environmental etc. Indeed, the limits of boundaries and bounties of planet earth are under enormous pressure which according to some analysts and scientists could pose an existential threat to the earth's systems and human societies in terms of depletion of earth's carrying capacity, habitat space and loss of food, water and biodiversity resources.

In the midst of the multiplicity, complexity and enormity of these challenges, however, human endeavor to expand the frontiers of knowledge and benefit from science and technology unfolds a plethora of opportunities to successfully negotiate and overcome these bourgeoning impediments and develop sustainable solutions for the survival and sustenance of human species and the planetary ecosystem. These issues are not simple to address. However, the investment and advancement in science and technology do provide a range of new tools, systems and ways to tackle most of the pressing and emerging issues which the world faces. The prerequisite is the national and global commitment of the political leadership and social and economic institutions to drive knowledge and technology-led development paradigm and promote innovative thinking and collaboration. Equally important is the need to fully understand the rapidity of innovation and technological development and the ensuing challenges for the policy-makers and national economies to make rational

choices, in particular, the ability to remain sustainably competitive and relevant in the pursuit of people-centered national development goals. This unequivocally highlights the importance of singularly distinguishable factor all through the history of mankind i.e., the pre-dominant role which science, technology and innovation (STI) plays in defining and determining the course of national as well as global political, social and economic structures.

The technological change and innovation, admittedly, are spurred by the dynamic amalgam of practical knowledge, creativity and disciplined theoretical discourse mediated by a complex set of relationships among various actors and players including enterprises, universities and government research institutes. The traditional technology development model is primarily based on inputs e.g., expenditures in research and development and outputs e.g., patents for new technologies. These are though important, the dynamics and network of interactions among the major players and actors involved in technology and knowledge product development have assumed the central role in STI advancement. In this interaction and role-play, the character and configuration of changing economic patterns, increasing specialization of industrial structure and the associated institutions of a highly globalized and competitive world constitute the pivot for the system of innovation and technology development.

The evidence abounds that at the national level, the STI has also underscored the imperative for collaborative action and synergy among the quartet of government, private sector, citizens and social institutions (especially the knowledge generating system) on almost all issues. Within the geo-economic and geo-political context, these issues include all dimensions of human security and areas of human development activity enveloping international institutions, the environment, private sector businesses, research and development, intellectual property rights, ethics, law etc. Consequently, the S&T related public policy and institutional setting constantly encounter a formidable set of challenges to remain

responsive and relevant to be able to generate and disseminate integrated solutions in the national as well as global quest for sustainable human development. A robust national innovation system is a prerequisite in this regard.

It is, as such, extremely important that the policy and decision-makers gain a comprehensive understanding and insight into the S&T potential and make robust policy decisions to accelerate the pace of innovation and technological development for ultimate transformation of the economic structure to the knowledge based economy. For this purpose, the most plausible and tried and tested way forward seems to be the establishment of a potently functional National Innovation System (NIS) covering all tiers across all sectors to muster and channel a collective effort of government, private sector and universities towards innovation and technology development. This will also entail a systemic approach to nurture a wider societal culture and ethos to promote creativity, enquiry, research and appetite for expanding the frontiers of knowledge and technology. Indeed, NIS serves as a platform and environment to allow a smooth flow of technology and knowledge (both tacit and codified information among people, enterprises and institutions) and vertical and horizontal connectivity, networking among the actors, enterprises, universities and research institutions. It also augments their capacity to (i) identify and develop new technologies and innovations through joint research, co-patenting, co-publications and (ii) improve industries' adoption rates for new technologies and upgradation of the technical know-how and expertise of their productivity gains and competitiveness.

Several countries of the world, especially during the post-World War II period, managed to achieve a massive transformation from extremely impoverished and poor economies to upper middle and high income wealthy nations essentially because of conscious policy and strategic choices toward adoption of technology and knowledge-led development model for sustainable economic growth. In Asia, China, South Korea, Singapore and Taiwan particularly present eloquent

testimony for their success as a result of establishing a robust and well-resourced national innovation and technology system.

Pakistan, on independence, inherited very meagre S&T resources and industries. However, in the decades of 1950s and 1960s, the government accorded a priority focus on scientific and technological development based on four components: colleges and universities for research and human resource development; S&T organizations for technology development; vocational institutes for skills development; and, S&T Councils to plan and govern S&T advancements. The post 1960s decades witnessed assiduous decadence, disintegration and disconnect between S&T, industry and economic development. The nationalization policy of the 1970s hampered industrialization and relapsed S&T into quarantine and regressive mode. Even the modicum of industrial growth in the absence of S&T connect, lacked technology transfer and competitiveness and reduced the industry to a trading venture without much value.[1]

The turn of the millennium showed some positive S&T outcomes e.g., emphasis on higher education and advancement in telecommunication, banking sector, real estate and defense technologies though food, water, social, health and economic security of Pakistan continue to remain vulnerable. The major challenge for the country, however, continues to be how to make use of S&T as an asset that drives value addition, creates a knowledge economy, generates wealth and, makes Pakistan globally competitive. S&T led interventions help and address major issues of poverty, deprivation and decadent economy marked by stagnant exports, rising imports, trade deficit, slow growth in GDP, and poor performance on other development indicators.[2]

This book, based on two years of rigorous research, attempts to recommend a workable way forward to fully harness S&T potential and establish a robust National Innovation System as a stepping stone for adopting a virtuous cycle of technology and knowledge-led economic paradigm. The research and analytical work involved, the review of best

practices and what worked what did not work around the world. It is based on qualitative analysis and consultations with renowned industrialists, senior government functionaries and members of the academia, and, has used a quantitative analytical framework to validate the findings and outcomes. This mixed approach of amalgam of qualitative and quantitative analysis indeed signifies a pioneering effort in the IS discourse and scholarship as the majority of the existing literature on IS approach has employed either the qualitative approach or the quantitative models while exploring the innovation system terrain.

The prime assertion of the book is that Pakistan needs a compelling vision that drives, integrates, and directs the entire nation into a single agenda of the knowledge economy: "Developing Innovative Pakistan" with a focus on three components: (a) wealth creation; (b) poverty alleviation; and (c) sustainable growth. This, a priori, entails strong political ownership, commitment of the university and research system and active engagement of the private sector reinforced by solid resource allocation and investment in S&T, basic education for quality human resources, technology adoption, and diffusion especially, commercialization of available technologies through startups and large-scale enterprises. This would also require shunning of the traditional linear model of technology development and, instead, adoption of the emerging dynamic S&T advancements framework fully guided by the methods of innovation, areas of innovation, and speed of innovation. The new rule of the technology world is "the fastest technology application and commercialization invented by anyone".

Another unique feature of this book is that it suggests a concrete intervention model and implementation framework with clearly articulated roles and responsibilities at various tiers of governance of the major actors and entities in the technology and innovation ecosystem.

The book comprises eight parts. Part I introduces the theoretical and conceptual evolution of the Innovation System framework (IS) together with a brief description of the competing frameworks and the

prerequisites for application of IS to drive sustainable economic growth and development. Part II, while dwelling on the characteristics and structure of the economy of Pakistan highlights the importance of technology and innovation not only to catch up the huge technological lag both in the region and the globe but also to transform the obsolescence of the existing economic architecture to a technology-led knowledge economy paradigm for regaining competitiveness, productivity and sustainable growth. Part III recounts the history of the technology and innovation saga in Pakistan, specifically identifying the periods, decades and the S&T vicissitudes witnessed by the country ever since its inception. This historical account is followed by Part IV which gives an analysis of the performance of some selected indigenous industries including rice, automotive, defense and telecom sectors for improvisation, development and dissemination of technology and innovation.

Part V of the book attempts to prescribe the configuration of the IS framework for its application to Pakistan. It also scans the learning and experience of some lead knowledge and technology-led economies and models including China, South Korea, MIT model of the US and innovation-led growth through technological reservoir of the world. Part VI encapsulates the rationale as well as the theoretical basis comprising qualitative and quantitative analysis for gaining the perspective of major players on the existing S&T canvass of the country i.e., government, firms and industry, and, the knowledge infrastructure.

Against this backdrop, Part VII of the book provides a comparative analysis of the S&IT landscape in terms of Gross Domestic Expenditure on R&D (GERD) and data on Patents vis-à-vis some selected countries such as India, Vietnam, Egypt and the Philippines. Part VIII describes major issues and challenges that constrain the S&T and IS development in Pakistan including the lackadaisical role of the government, the evasiveness of the private sector to pursue technology-based productivity gains and competitiveness, the apathy of the knowledge infrastructure to harness and drive S&IT potential and finally the digital

divide as the major impediments to S&T and IS development. Part IX embodies the specific recommendations, way forward, implementation framework and intervention model for establishing a robust and functional National Innovation System in Pakistan to embark on innovation- led growth and shift its trading economy into a value-added production economy and ultimately knowledge economy.

As a valedictory note, it may be added that the world has gone far ahead and already embracing Industrial Revolution 5 (IR5) much beyond Industrial Revolution 4 (IR4). IR4 advocated technology- driven long-term efficiency and productivity gains to lead to sustainable economic growth, enhancement of income levels and improvement in the quality of life of people around the world. IR5 on the other hand is value-driven and highlights R&D importance to support the industry in its long-term service to humanity within planetary boundaries where the human and machine reconcile and work in symbiosis and complementarity to exploit the strengths of each and compensate for their corresponding weaknesses. Human - centricity, sustainability and resilience constitute the kernel of mankind's effort to harness technology for sustainable human development.

Notes

1 https://www.researchgate.net/publication/371349177_ST_Governance_of_Pakistan -Turning_Liability_into_Asset " Shahid Najam, Dec 2021

2 On the global competitiveness index Pakistan ranks 115 among 140 countries- a sad reflection on S&T sector

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"Technological innovation and economic progress are like a fragile and vulnerable plant, whose flourishing is not only dependent on the appropriate surroundings and climate, but whose life is almost always short."

Joel Mokyr, Northwestern University, 1990

"Innovative activity has been the single, most important component of long-term economic growth."

Nathan Rosenberg, Stanford University, 2005

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Part I: Innovation System Framework

1. Introduction

Several countries of the world achieved a massive economic transformation during the post-World War II period from extremely impoverished and poor economies to upper middle- and high-income wealthy nations. They have since successfully sustained steady economic growth and human development gains. This was essentially due to a conscious policy decision and the national consensual political commitment to develop a knowledge based economy[1] spurred by a robust and well-resourced national innovation and technology system. Notable among these countries in Asia are: China, South Korea, Singapore and Taiwan. China's Gross Domestic Product (GDP) in 1960 was $59.72 billion which in 2022 became $17.96 trillion[2] and registered a massive growth by a factor of 300 plus with its ranking on the Human Development Index (HDI) in 2024 at 75 out of 193 countries and per capita income of US$13,160.[3] It has become the world's largest economy (on a purchasing power parity basis), manufacturer, merchandise trader, and holder of foreign exchange reserves. Taiwan was a poor country in 1960 with GDP per capita $150 and overall GDP of $1594 million but performed the spectacular appellation of "economic miracle" in 1990s as it embarked on knowledge based industrial growth during 1980s.[4] Its overall GDP is around $752 billion in 2023 and per capita income of around US$34,143 in 2023.[5] [6] South Korea in 1960 was also a very poor country with GDP of $3.96 billion and per capita GDP of only US$ 1589, which in 2022 stood at $1.6 trillion and per capita income of $32,422[7] with HDI ranking of 19 out of the 193 countries in 2024. Similarly, Singapore's GDP per capita was less than US$450 in 1960 which now stands at US$82,807[8] with HDI ranking of 9 out of 193 countries in 2024. Pakistan which was far ahead of many South Asian countries in 1960s,[9] however, ranks 164 out of 193 countries on HDI and per capita income of around $1589 in 2022.[10] One common feature of the development experience of countries like China,

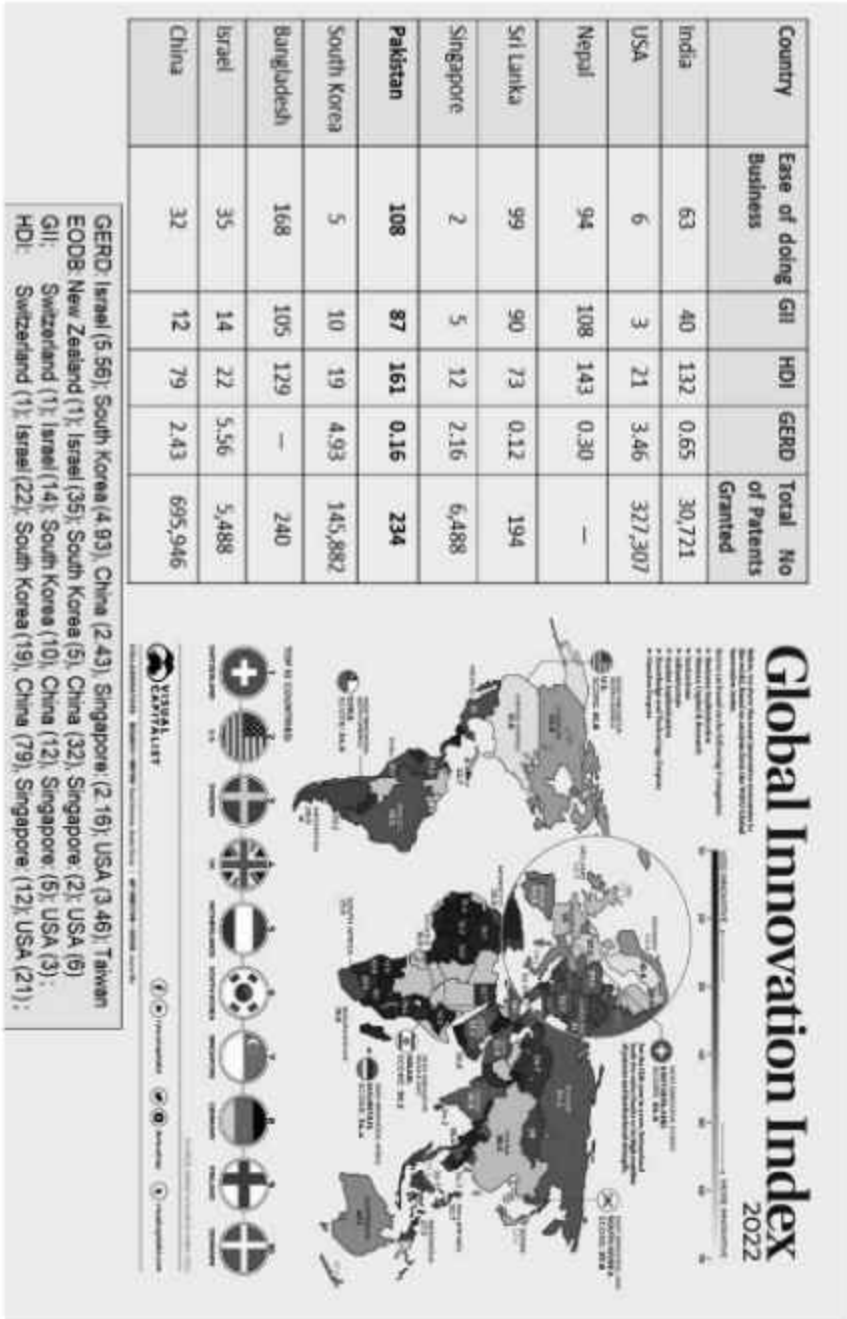
Taiwan, South Korea and Singapore has been the focus on the knowledge based economic paradigm characterized by progressive advancement in scientific innovation, improvisation and development of technology, competitiveness and human capital formation. They are now among the leading innovative economies in the world and major drivers for ushering in the digital age and the deep science innovation to sustain the economic uplift within their respective countries and are contributing to address the major development challenges of the planet. According to the World Intellectual Property Organization (WIPO), Global Innovation Index (GII)[11] which tracks the most recent global innovation trends, takes the pulse of growth and productivity and ranks the countries based on certain indicators like their success and capacity in innovation, political environment and knowledge creation of the economies etc., Switzerland was the most innovative economy in the world in 2022 followed by the United States, Sweden, the United Kingdom and the Netherlands. Korea occupied 6th position while Singapore figured at number 7 and China at number 11. Pakistan, though performed above expectations on the innovation index relative to its economic development, secured 87th rank out of 131 countries. The figure 1 captures the world ranking in 2022 on GII, EODB, HDI etc.

The poor progress of Pakistan is primarily due to the low priority accorded to the design and implementation of a National Innovation System (NIS) and the integration of scientific knowledge and technology in its development and economic growth strategy.

Innovation System Framework: A review of the relevant literature on science, technology and innovation invariably suggests that the establishment of an efficiently functional NIS[12] and formulation of STI policies are prerequisites for a smooth transition to knowledge economy (Chaminade et al., 2018).[13] There are, however, a variety of options of which NIS is considered to be one of the most powerful frameworks and standard reference for laying the knowledge economy foundations. NIS helps understand the science and technology (S&T) capabilities of a nation-state and prescribes policy measures for overcoming the constraints

to its innovation and technology development.

Figure 1: Global Innovation Index 2022 and other Indices



Country	Ease of doing Business	GII	HDI	GERD	Total No of Patents Granted
India	63	40	132	0.65	30,721
USA	6	3	21	3.46	327,307
Nepal	94	108	143	0.30	—
Sri Lanka	99	90	73	0.12	194
Singapore	2	5	12	2.16	6,488
Pakistan	**108**	**87**	**161**	**0.16**	**234**
South Korea	5	10	19	4.93	145,882
Bangladesh	168	105	129	—	240
Israel	35	14	22	5.56	5,488
China	32	12	79	2.43	695,946

GERD: Israel (5.56); South Korea (4.93); China (2.43); Singapore (2.16); USA (3.46); Taiwan
EODB: New Zealand (1); Israel (35); South Korea (5); China (32); Singapore (2); USA (6)
GII: Switzerland (1); Israel (14); South Korea (10); China (12); Singapore (5); USA (3);
HDI: Switzerland (1); Israel (22); South Korea (19); China (79); Singapore (12); USA (21);

Source: Global Innovation Index 2022

The framework is also being widely employed as a strategy for catching up the development lag (Sesay et al., 2018).[14] A unique and distinctive feature of the framework is its flexibility to take into account variability, different contexts and peculiarities of the specific socioeconomic environments of the nation-state to understand country specific innovation system (IS) situation. As such, it serves as a strong and reliable evidence-based tool for researchers, academia, policy-makers and development practitioners in their descriptive, diagnostic and prescriptive analysis to propose country specific recommendations to build a robust innovation and technology development system and consequently the knowledge economy.

As from the 1990s, the NIS framework has been used by various donors, development partners and multilateral agencies e.g., the Organization for Economic Cooperation and Development (OECD) etc., as an analytical and prescriptive tool for designing S&T policies and achieving economic growth, competitiveness and inclusive and sustainable development in the globalized world. In fact, Canada and Finland pioneered the implementation of IS framework as a strategy for economic growth. The framework is very useful especially for developing countries both to catch up for the economic development lag and to pave the way for establishing a knowledge economy. The national economies, however, differ in terms of policy landscape, institutional arrangements, degree of specialization and mode of innovation. The IS concept has the flexibility to adapt to country-specific requirements and use country as a unit of analysis to inform policy-makers and all the stakeholders at the national level on what they need to do to improve their science, technology and innovation (STI) performance for sustainable economic growth and development.

2. The Conceptual Evolution of National Innovation System (NIS)

The NIS concept was originally developed by its pioneers Freeman (1987) and Lundvall (1988, 1992)[15] while carrying out a case study on Japanese NIS to gain a better understanding of national economic

performance in terms of growth and competitiveness through technological interventions. They focused on experience-based learning and tacit knowledge through the broader definition of NIS and gave special attention to the organizations and institutions situated or rooted in a nation-state and involved in the process of innovation through interaction. This broader definition encompassed capability building and diversity of learning paths as the basic building blocks of development.

Though they were all influenced by Schumpeter to the extent that innovation is important for economic development,[16] the NIS concept which they developed is distinctively different from Schumpeter's work in multiple ways (Chaminade et al., 2018). First, Schumpeter referred to innovation as heroic acts of entrepreneurs and/or the result of the efforts of big oligopolistic firms. Second, he had a supply focus. There was little, or no mention of the demand side and the major assumption was that users would themselves adjust to innovations coming from the suppliers and producers. Third, Schumpeter was more interested in big and radical innovations as he considered those to have an impact on economic development. Incremental innovations were conspicuously missing in his discussion. Last, he paid little heed to government intervention in fostering innovation, implying its insignificant role in the innovation and technology development.

The IS conceptual framework of Freeman and Lundvall and later Nelson was broader and tried to explain not only the impact of innovation on the economic development of a country but also the rate and direction of innovation. In their treatment of innovation, demand side was as important as the supply side where users played a key role in the innovation process. They also emphasized incremental innovation, innovation diffusion and organizational learning besides big and radical innovations while urging the government to create a conducive policy environment for promoting innovation and innovation-based growth. Finally, and most importantly, their system's concept referred to components and in the case of NIS these components are: private sector,

research and learning systems and innovation-technology generation institutions. They are embedded in the nation-state that are interrelated and need to be brought together to create synergies where the whole is more than the sum of its parts (Kline & Rosenberg, 1986; Lundvall, 1985).[17]

Nelson (1993) and Edquist (1997) subsequently narrowed down the NIS definition emphasizing the interaction between firms and research institutions.[18] The focus of their definition and explanations was science-based learning and codified knowledge. The differences between the narrow and broad definitions of the NIS are described in Table 1.

As is evident from Table 1, broad definition of NIS as compared to its narrow definition is potentially more relevant and effective to serve as a robust conceptual framework to assess and understand the status of IS of a country, especially a developing one. More specifically, the following considerations primarily support the adoption of the broader definition as a preferred analytical and prescriptive tool:

- First, governance is largely localized at the level of a nation-state and there remains a strong need to have an analytical framework that can produce insights through which national governments can design STI policies for growth, development, and competitiveness of their countries.

- Second, STI empirical research shows that countries differ in terms of institutions, specialization, and mode of innovation – contexts vary considerably across economies. As there is very little convergence among nations on these dimensions, NIS, remains a useful framework as it considers a national system as its analytical unit.

- Third, there is a need for localization of different kinds of knowledge and modes of learning. Both formal and informal institutions play a significant role in shaping human resource development for localization of knowledge and modes of learning

which, to a high degree, have to remain nation specific.

- Fourth, globalization has created new challenges for national institutions and governance because of transnational flows of people, capital and knowledge. In this circumstance, it is vital to understand these new challenges for the national institutions through a framework which focuses on the nation-state.

Table 1: Difference between Narrow and Broad Definitions of NIS

Parameters	Narrow Definition	Broad Definition
Main Pillar	National Science System	Knowledge is considered important resource and learning the most importantprocess in an economy
Focus	Science-based learning, radical innovations, and firm-level STI learning	STI and DUI (learning by doing, using, and interacting), user-producer interaction and incremental innovations
Implications for Policy	Promotion of science-based learning and R&D expenditure	Framework conditions to improve learning across organizational borders, considering the institutions effecting learning, promoting experience-based learning and tacit knowledge and diffusion of technologies

Source: Adapted from Chaminade et al. (2018)

The broad definition of NIS albeit has major implications for economic development depending upon the country specific economic settings. It is, therefore, important to understand a country's local context to be able to comprehensively understand and apply NIS components to the country. The broad definition of NIS places special emphasis on the diversity of learning which underlines building of knowledge and competence through experience- based learning – learning by doing, science-based learning and/or processes of discovery. This unfolds a variety of learning paths through a combination of different modes. This particular aspect of broad definition is extremely relevant for a developing

country like Pakistan where traditional or indigenous knowledge, often of a highly tacit nature, is intensely localized and transmitted in small social communities and coexists with more universally applied scientific knowledge[19] (Kraemer-Mbula & Wamae, 2010). Although formal university education remains important as the broad definition appreciates, the diversity of learning paths e.g., phenomena like on-the-job learning and technical training can cater to different learning needs of different people throughout their lives.

The broad definition also emphasizes the need for linkages within the organizations (how firms and other organizations support processes of learning and experimentation, problem solving and creativity) as well as linkages between different organizations (inter-firm networks). These linkages may be formally established in developed country settings but in developing economies especially the least developed ones, there is a high degree of informality. Many households and unregistered businesses account for a considerable proportion of employment and production. In these developing countries, it is essential to understand how innovation is organized in the informal sector, how it is linked to the formal economy and how NISs can capture processes of learning, competence building and innovation in the informal economy.

It may be emphasized here that knowledge flows and sharing within and between organizations and what is the level of trust between them is determined by social structures. Trust reduces transaction costs and facilitates the transfer of knowledge through formal and informal networks, which ultimately impacts innovation performance (Lundvall, 2002).[20] A broader definition of NIS concept helps understand the social structure of a country and how knowledge flows within and between organizations and what the degree of trust is.

3. Innovation System and the Competing Frameworks

In addition to the broad definition of IS developed by Freeman and Lundvall, there are several other competing options to design NIS notably

the Innovation Ecosystem (Moore, 1993), National Business System (Whitley, 1994), Triple Helix (Etzkowitz & Leydesdorff, 2000), National Learning Systems (Viotti, 2002), and National Entrepreneurial Systems (Acs et al., 2014) to systemically harness the innovation and technology potential for economic development and growth.[21] The salient characteristics of each one of these alternative frameworks are as under:

Innovation Ecosystems: Ecosystem as a conceptual framework is mainly used in management literature and refers to the consumers and producers and set of inter se relationships contributing to any organization's performance (Moore, 1993). In the Innovation Ecosystem concept, at the center are the firms along with their suppliers and customers all of whom create value in the institutional,organizational and operational environment.

National Business Systems: The National Business Systems (NBS) focuses on a strong relationship between social institutions and how firms and markets interact in distinctive business systems to respond to the need for technological advancement and innovation. These interactions between firms and markets may vary across different institutional settings. The approach was proposed by Whitley (1994) after analyzing the variations in the economic organizations and experiences in East Asian economies.

***Triple Helix*:** The Triple Helix (TH) approach, expounded by Etzkowitz and Leydesdorff (2000) underlines that at the core of the innovation activity is the university as a knowledge producing agent. He treats innovation as a systemic process and links university, industry and government for analyzing innovation at sectoral, regional, national or transnational levels.

National Learning Systems (NLSs): Viotti in 2002 came up with a new approach on technological change based on the evidence of the economic development path espoused by Brazil and South Korea. He advocated that the process of technical change is not so much generated

by innovation. Instead, it is a process of learning. He postulated that the technical change is achieved by the absorption of already existing techniques, i.e., of innovations engendered elsewhere, and/or the improvements made around the acquired innovations. He presented two types of NLSs - passive and active. The former is directed and driven by the primacy of technology absorption and its diffusion and consequent incremental innovation achieved through the production capabilities. The latter is characterized by a deliberate and consistent technological learning effort that focuses on the mastering and full acquisition and constant improvement of the absorbed technologies of production.[22]

National Entrepreneurial System: Acs and his co-researchers introduced a novel concept of National Entrepreneurship System (NES) as fundamentally resource allocation systems that are motivated by individual- level pursuit of opportunity through the creation of new ventures contextualized within the country-specific institutional arrangements. Distinct from the National Systems of Innovation frameworks, where institutions engender and regulate action, these systems are driven by the individuals with the role of institutions confined to regulate the outcomes of individual action. The salient characteristics of NES include (i) espousal of a systemic approach to allow interactions between components of NES; (ii) identification of bottleneck factors that hold back system performance; and (iii) contextualization of national entrepreneurship processes within the country-specific institutional framework.[23]

In comparison with these frameworks, the IS approach adumbrated by Freeman (1995) seems to be the most feasible as it provides a greater opportunity for countries like Pakistan to move forward. It enables the countries to embark on structural transformation towards a knowledge economy and spur acquisition of knowledge and know-how, generate technology and create diffusion culture for its S&T capability development.

The economic development and growth path which Germany

adopted had already successively demonstrated that it did not entirely depend upon a laissez faire approach. Instead, it focused on the acquisition of technology and education to successfully catch up and surpass other European countries including Britain in knowledge generation, accumulation, diffusion and in linking education, research and training systems (Freeman 1995).[24] The setting up of R&D laboratories by the private sector in Germany and the US and the development of strong national research infrastructure also led these countries to generate wealth, technological leadership and competitiveness. In both countries, besides R&D labs, linkages were built between enterprises and public knowledge infrastructure where private firms could benefit from public investments, particularly in military and health research. Long-term futuristic investments in education, learning and skills development, incentives for innovation through user-producer interaction and commitment to international competitiveness coupled with the support of robust institutional arrangements were integral parts of the national effort to build these countries' NIS.

The successful experience of these countries gave impetus to the wide adoption and salience of NIC concept as an analytical framework in the 1990's not only by the academic or research institutions but also by multi-lateral organizations like the Organization for Economic Co-operation and Development, the European Union and the United Nations Conference on Trade and Development (Sharif, 2005).[25] The World Bank and the International Monetary Fund (IMF) also began to employ it for understanding the national competitiveness of various states while the United States National Academy of Sciences extensively made use of the IS concept for analyzing S&T policy (Lundvall & Tomlinson 2002).[26] Later, the NIS concept, because of its inherent strength became a potent and well-recognized analytical framework for a wider set of policy issues such as those related to economic, sustainable and inclusive development going much beyond its original remit to explain and better understand the national economic performance in terms of growth and competitiveness (Chaminade et al., 2018).

4. Prerequisites for Innovation System Framework

The implementation of IS experience suggests that innovation and technology development hinges upon the efficacy of a complex set of relationships and dynamic interaction and the degree of functional integration, operational linkages and coordinated effort among the major actors and entities engaged in knowledge and technology generation and dissemination i.e., the troika of government, university and research system and private enterprises. The efficient functioning of the IS is generally determined and guided by four types of knowledge or information flows: (a) interactions among university system, research institutions and private industry and enterprises through joint research, co-patenting, co-publications and technical collaboration; (b) training and capacity development of industry by university system with support of government institutions by establishing knowledge shops within the industrial estates and clusters; (c) diffusion of knowledge and technology, both tacit or informal exchange of know-how and codified knowledge and patents, to enterprises and strengthening industry's technology assimilation and adoption capacity through incentives in the shape of machinery and equipment; and (d) mobility and horizontal movement of technical personnel and expertise within and between the public and private sectors. This close-knit integration between university and research system, government and private sector and flow and exchange of information and knowledge leads to rapid technology diffusion and improved innovative capacity of enterprises in terms of products, patents, productivity, profitability and sustainability in economic performance.

However, smooth functional integration, a prior, requires the identification of the constraints both at the upstream policy and downstream operational levels that prevent the flow of information and knowledge. These constraints foment mismatches within the system to consequently, thwart technology development and innovation.

At the same time, it is equally important to leverage the linkages and provide stimulus for enhancing coordinated innovative performance

and competitiveness as well as better networking and collaboration among the actors and institutions in the system. This helps nurture and strengthen the culture and capacity for improvisation, development, dissemination and absorption of innovations and technologies. At the same time, an assessment or gap analysis and mapping of the existing knowledge flows, state of institutional linkages and movement of inter industry human resources should be carried out to further elaborate on the constraints. This should be coupled with an evaluation of the efficacy of the industrial clusters and the capacity of the private sector firms and university and research institutions in the course of the diagnostic exercise.

The knowledge, innovation and technology development also entail existence of a conducive policy and regulatory environment to protect intellectual property rights and patents and promote institutionalized interaction within the overall IS through joint industry research, public/private sector partnership and sharing of best practices. This needs to be accompanied by adequate resource allocation and investment for research and development and a progressive and rigorous implementation of the NIS approach which, together, lay down a robust foundation for embarking on a knowledge based economy. The choice to pursue a knowledge-economy paradigm, however, as a paramount imperative entails strong political will and commitment at the highest level, fully informed of the costs, risks and possible failures and lags in transformation of the existing structures.

5. Application of Innovation System Framework (ISF)

The IS Framework provides a robust and rational basis to study and assess the existing, emerging and the potential of new technologies and innovation for sustained economic development and growth. It also helps to gain meaningful insights for the policy-makers and other actors and institutions into the entirety of technology and innovation landscape including social, economic, collaborative and relational intermediaries, R&D and non-R&D entities. It facilitates a full grasp of the knowledge flow among them, to influence and give impetus to the national and sectoral

technology development and innovation capacity. More specifically, some of the salient purposes and objectives that could be achieved by deploying IS Framework (ISF) include:

a) Understanding Technological Capabilities of a Country: A Typology of ISs and Degree of Economic Development

ISF serves as a comprehensive analytical tool to map and understand the technological capabilities of a country. The framework comprises various typologies. A specific typology, corresponding to the degree and level of economic development of a country, could be deployed for a diagnostic analysis and general understanding of its IS's technological capabilities.[27] There are three types of ISs ranging from the most sophisticated to the least sophisticated as follows:

(i) Mature IS

The ISs of economically developed and high-income countries are categorized as mature ISs. All the important building blocks of an IS – relevant organizations, institutions and socioeconomic structures determining the rate and direction of innovation – are in place and the relationship and interaction between them are robust and solid. Some examples of the mature ISs are Sweden, Denmark and Singapore.[28] Denmark, as innovation leader, achieved the target of Europe's R&D intensity of 3% of GDP in 2020 with focus on building "the most effective bridges between research-based knowledge building and the application of this knowledge in business and society".[29] Singapore IS helped it to move from 3rd world to 1st world status in just 40 years and to be able to advance the technological frontiers. The government policy emphasized on technological intensification (science parks and technology infrastructure), institutional support through incubators agencies and promotion of local high-tech sector, the applied R&D investment by multi-national corporations, enhanced funding of the R&D institutions and university-based research and focus on developing human capital (critical thinking skills development, re-design of the syllabus, reformed

assessment and evaluation model). Primacy of the process rather than outcome was coupled with learning i.e., learning by doing, learning by transaction, learning to innovate and learning to pioneer which constituted the essence of the innovation system.[30]

Albeit, high income countries or mature ISs also face several challenges. Their absolute advantage is at stake if they do not respond effectively to technological changes. History is a witness that with technological revolutions some incumbent countries remained locked in old technologies while few other countries used the window of opportunity afforded by the new technologies to become the new leaders (Chaminade et al., 2018). For sustaining development, these high-income countries, therefore, need to explore new technological opportunities and diversify into new areas.

(ii) Dual IS

The ISs of middle and high middle-income countries can be put under the category of dual ISs. In this type of IS, some highly innovative industries or clusters of industries co-exist with underdeveloped industries having technology and innovation capabilities. In dual NISs there is presence of a critical mass of science, technology, engineering, and mathematics (STEM) workers who engage in STI modes of learning in innovative industries. However, in the conventional industries of these NISs, the major mode of learning and technological advancement is learning by doing. The traditional manufacturing industries and subsistence or semi-commercial agriculture are the dominant economic activities in dual ISs. Some examples of dual NISs are Brazil, China, and India.

In case of Brazil,[31] the policy (Policy for Industry, Technology and Foreign Trade-PITCE-of 2003) emphasis was to pursue a systematic strategy to foster continuous product and process innovation in nationally-owned enterprises and smooth exchange of information among major

actors i.e., government, university system and industry. This was backed by appropriate institutional and regulatory structures, financial support and subsidy for R&D and strategic partnerships between universities, research institutions and firms, macro-economic solidity, promotion of research institutions, growth of dynamic large nationally-owned enterprises. The private enterprises were also encouraged to foster innovation. The small and medium-sized enterprises (SMEs), it was believed, would benefit through integration of the larger enterprises with the global markets.[32]

India after independence in 1947, witnessed a steady transformation from a rural agricultural-based economy to an industrialized economy with a pervasive and burgeoning innovation-technology led service sector. The Indian NIS underwent, especially since the beginning of 21st century a qualitative change from public-sector led inward-looking closed system to a more open system allowing large firms/conglomerates to play a central role in generating innovation and technological advancement in crucial sectors The NIS framework with the economic development plans, apart from boosting industrialization, helped India establish a number of S&T agencies, universities and institutes of technology, finance institutions and build critical mass of educated-skilled worker for the industrial and technological activities. Joint Ventures between the state-owned companies and foreign corporations especially Japanese served as technology transfer and knowledge platform and also stimulated growth of private research institutes. With conducive institutional and policy environment (S&T policies of 2013 and 2020), active role of the universities and institutes of technology and the private sector R&D initiatives, India, at present, claims to be the hub of technology and innovation especially in the emerging economies. However, despite this progress, heterogeneity continues to pose a major challenge to Indian NIS which is marked by a robust and dynamic system of international standing in some selected sectors (defense, nuclear, automative, pharmaceuticals etc.), and strong sectoral unevenness e.g., concentration of R&D on large firms, the innovation deficit of small and medium enterprise (SMEs), and low value addition of the manufactured products.[33]

As regards China, the highly systemic reforms in the R&D system were initiated in 1985 with focus on reshaping the interaction between the state owned industry and knowledge and innovation generating systems. With policy of economic liberalization, knowledge and innovation creation patterns drastically evolved into forming a complete, balanced and developed national innovation system. The enterprises as the main entity, regional innovation systems, strong civil-military nexus, and pro-active role of intermediaries and the universities and research institutes together contributed enormously to the development of a strong NIS framework. National long and Medium Term Planning on Science and Technology (2006-2020) further provided the overarching environment with focus, inter alia, on investment in R&D and on full time equivalent personnel in R&D and close linkage between the industry and universities.[34]

The development challenges of middle-income countries with dual ISs are also different from low-income countries. As these countries move up the ladder of economic development, higher wages of labor erode the cost-based advantage of their export industries (Lee, 2013).[35] This can have an adverse effect on those middle-income countries which have few export industries like the software industry in India. Besides this, middle income countries may also face a scarcity of qualified labor due to brain drain which may act as a hurdle for development of main export industries or diversification of the economy. To escape the middle-income trap and move into a mature IS, these countries need to work on increasing investments in product and process innovation and move to higher value addition activities and diversification through better talent management. Technological capabilities need to be developed through policy measures and investments in higher education and encouraging technological knowledge to boost exports. There is also a crucial role of private R&D efforts in these countries for increased access to learning and knowledge for attaining the required technological capabilities (Lee & Kim, 2009).[36]

(iii) Emergent IS

Emergent ISs can be found in low and lower middle-income

countries such as those in Africa, Central America and South Asia including Pakistan. These ISs are in their early stages of development characterized by the availability of some of the components of IS such as universities, firms and intermediate organizations. However, these components largely suffer from low technological capabilities, weak inter-organizational formal linkages, limited basic infrastructure, uncertain business environment and fragmented institutional framework besides limited human capital. STI learning might take place in some organizations but learning by doing and apprenticeships dominate economic activities in the emergent NISs.

Africa, on the whole could not develop a robust innovation system. The literature on the subject reveals that it generally followed two tracks to innovation: one internationally-oriented, based on technology acquisition through trade and modicum of FDI (though excessive dependence on natural resources and primary commodities) and economic integration and accompanying investment for export specialization and knowledge spillover and social entrepreneurial capital development for innovation (Egypt, Ivory Coast, Kenya, Nigeria, Rwanda, Tunisia, Uganda, Zambia etc.); and the other domestically driven, for relatively higher-income countries, primarily through financial inclusion to integrate unbanked segments, investment in human capital, governance and institutional reforms, internet usage and bridging the digital divide and the higher level of FDI (Mauritius, Morocco, South Africa, Tunisia). More specifically, in most of the countries, adaptive and incremental industrial innovation took place despite a range of constraints- policy, infrastructural, institutional, and lack of integration of local firms with the university system. Africa, however, shows resourcefulness and an ability for deploying and developing technology for specific needs (financial inclusion, reducing digital divide, joining free trade arrangements for accelerated innovation, especially in poorer countries), and improvements in the quality of life. The financial inclusion is likely to led to improvement of the quality of scientific research institutions, greater private sector spending on R&D and university-industry collaboration in R&D. Africa

needs to go beyond paradigm of R&D to drive the economic growth to establishing robust NSIs framework both to catch and combat the enormity of development challenges including impact of climate change and sustainable development[37]

As regards, Latin America and the Caribbean, the national innovation systems are still in a developing stage. Judged from various parameters, they exhibit low-effort-low-priority innovation effort, dearth of qualified and skilled human resources, informal and *ad hoc* innovation sag, weak linkages and knowledge flows, and episodic engagement of the private sector in the R&D initiatives. Succinctly, the region's National Innovation Systems, though open for inflow of foreign technology as a major source of innovation (through FDI and technology acquisition), are afflicted with heterogeneity i.e., the most developed being Argentina, Brazil, Chile; second being Colombia, Costa Rica, Uruguay and English Speaking Caribbean with significant national capacity and specialized institutions to promote S&T; and very poorly endowed countries like Ecuador, El Salvador, Nicaragua, Peru with a significant absence of policies, institutions, and investments in national S&T development.[38]

Briefly, besides weak linkages between private firms and research institutes, there is a paucity of research products to be offered by research institutes to firms. Even the research carried out by university researchers is to pursue the research agendas set by the leading segments of the respective scientific or technical discipline in developed countries. The lack of comprehensive regulatory frameworks, intellectual property rights institutions, and information and technical services aggravates the problem. Governments thus need to address these systemic issues and play a pivotal role in shaping the policy landscape (Innovation Promotion Policies, Policies Aimed at Modifying Market Incentives, Fiscal Policies, Venture Capital Policies and Credit Policies) and catch-up strategy, planning framework and human capital development system to ultimately allow the Latin American and Caribbean countries take a steady transition from predominantly an imitation phase to knowledge-and-experience

accumulation stage. This will enable them to develop robust and enabling national innovation systems capable of responding to the needs of domestic firms and generation and diffusion of knowledge, innovation and technology for production of higher-quality, lower-cost competitive products.

Link between IS Types and Income Traps: The discussion on the typology of the ISs and the degree of economic development can also be linked to the issues and challenges faced by countries categorized under different types of ISs and the associated income traps. A particular type of IS can transition into other types, for example, with proper understanding of the challenges being faced by an emergent IS like Pakistan, appropriate policy responses can be formulated to catch up and transform into dual or mature IS. Similarly, a mature IS can become dysfunctional and move down to a dual IS if it does not review periodically its STI policy framework for effective performance of its innovation system.

Low or lower middle-income countries with emergent ISs are afflicted with low levels of education, wages and investment levels and engage in exports of primary goods which have volatile prices in foreign markets. Consequently, these countries are entrapped in low- income or poverty traps. From the perspective of catch up, these countries have to first consider economic development as a matter of self-transformation from within (Anderson & Axelsson, 2016; Metcalfe & Ramlogan, 2008).[39] Subsequently, they should work on improving their ISs by focusing on aspects like competence building, structural transformation and technological upgrading through imported technology improvisation and imitation.

Figure 2 shows the relationship between ISs, income traps and catching up.

Figure 2: ISs, Income Traps and Catching Up

Source: Chaminade et al. (2018)

There is no doubt that technological capabilities of firms and other organizations are stronger in developed countries than developing countries. It is primarily due to this reason that new technological opportunities are expected to emerge in developed countries. Developing countries through a proper understanding of their ISs and policy measures required can achieve a better position when it comes to absorbing and using new technologies. The case of nano-computers shows how the introduction of new generic technologies in low- income markets and interaction with low-income users may also reinvigorate the world of innovations (Harirchi & Chaminade, 2014).[40] The development of the telecom industry in China is another example of how a country moved to a world leading position through first addressing the needs of poor regions (Chaminadeet al., 2018). An encouraging lesson for developing countries like Pakistan is that the fragility of the institutional conditions may prevent innovation, but these might also give rise to those kinds of institutional experimentation which are required for the absorption of new technologies or technological systems.

To summarize, low or low-middle-income countries, like Pakistan, in their efforts to catch up and come out of the poverty trap, need to

understand their specific type of IS, their degree of economic development and the specific set of challenges they are facing. These countries have to create an overall enabling milieu for learning through investments in education and skills development. They need to also embark on institutional transformation of the existing rigid structures to flexible work organizations which can provide them with opportunities to move from low-income or low-middle-income to upper-middle-income and dual NIS. Technology and innovation must be used to move to higher value-added activities with a stronger emphasis on export orientation. Subsequently, they need to respond to increasingly sophisticated domestic markets which can provide opportunities to move from middle-income to high-income and a mature NIS.

Finally, proper conditions need to be created to allow experimentation in new technologies encouraging entrepreneurship and providing flexible institutions which may prevent mature ISs from becoming dysfunctional when they are faced with new technological challenges. However, one common aspect of all system dynamics and transformation is capability building and fostering diversity of learning through interactions.

b) A Framework for Catch-up and Economic Development

The IS conceptual framework is extremely relevant for developing countries to enable them to address the enormity of economic growth and development challenges. It may be underscored that development is a more holistic concept than economic growth. The latter provides a narrow insight into the distribution of wealth and improvement or deterioration of human living conditions and is merely concerned with the increase/decrease in consumption and production of goods and services as manifested by the gross domestic product (GDP) of a country. The former, on the other hand, encompasses economic, social, and environmental progress (Ayres, 1996).[41]

Both Freeman and Lundvall, inspired by the Latin American

Structuralist School (LASS), inter alia, used IS concept to demonstrate the success stories of technology catch-up and economic development of many third world countries. They also brought to the fore the role of technological change to pave the way for long-term economic development of any nation (see Freeman, 1982; Dosi et al., 1988; Lundvall, 1992; Nelson, 1993).[42] During the 1990s and early years of twenty first century, most of the empirical and theoretical work on IS was carried out in developed countries with stable socio-economic conditions and governments. This led critics like Viotti (2002) to argue against the relevance of the concept as an analytical framework to study the challenges of the developing countries and its applicability in unstable / volatile and middle- or low-income country environments.[43] However, the successful evolution of ISs in South Korea and Taiwan provided ample empirical evidence to validate equally the application of IS perspective as a robust framework to analyze, understand and address the growth and development challenges of developing and middle- income countries. The 'intensive learning' and rapid development of ISs by these low-income countries was instrumental in their successful "catch-up" effort. Developing countries like Pakistan, therefore, need to benefit and learn from this planned and intentional strategic economic management and development experience for catching up (Ge, 1999).[44]

It may be noted that the IS concept has the inherent capability to illustrate the dynamic interaction between the developments at macro as well as micro levels. It identifies the changes at the system level as the outcome of the learning processes and interaction at the micro level and, at the same time, spells out the macro-system's influence in shaping the learning, competence building and innovation processes at the micro level. It, therefore, serves as a bridge between development economics and innovation studies (Lundvall et al., 2009a) and enables the policy-makers to understand how changes at the macro level can influence learning, competence building and capability accumulation in the system.

The next Part II attempts to give an overall appraisal of Pakistan's

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Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: from national systems and "Mode 2" to a triple helix of university–industry–government relations. Research Policy, 29(2), 109-123;
Viotti, E. B. (2002). National learning systems: a new approach on technological change in late industrializing economies and evidences from the cases of Brazil and South
Korea. Technological Forecasting and Social Change, 69(7), 653-680 and Acs, Z. J., Autio, E., & Szerb, L. (2014). National systems of entrepreneurship: Measurement issues and policy implications. Research Policy, 43(3), 476-494.

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[27] The typology of the ISs is adapted from Lundvall et al. (2009b). Three types of ISs are delin-eated moving from the most sophisticated to the least sophisticated.

[28] The Swedish national innovation system and its relevance for the emergence of global innovation networks: Cristina Chaminade, Lund University, Sweden (Sweden ranking on international Science and Technology indicators such as the ones regularly published by the OECD or Eurostat is always very high in terms of percentage GDP investment on R&D, the number of full time R&D employees per 1000 employees, industrial structure dominated by large R&D intensive multinational groups, strong specialization in high-tech industries and services, the university system emphasis on human capital formation and participation in

Global innovation Networks comprising global research collaboration, global sourcing of technology and innovations and global generation of innovations)

29 Peer Review of Denmark's Research and Innovation (R&I) System, EU Jan 2019

30 The National Innovation System of Singapore Winston T. H. KOH Singapore Management University, 2010

31 In 2003, the government of President Lula was extremely cautious about its economic policy pronouncements, since it could not be seen as straying from the path of macro-economic solidity. research institutions and private enterprises to foster innovation. It did support small and medium-sized enterprises (SMEs), but believed that consistent innovation processes and integration into global markets were best achieved by fostering the growth of dynamic large nationally-owned enterprises (Federal Government of Brazil 2003). The government's objectives were to (i) encourage R&D and strategic partnerships between universities, research institutions and firms; (ii) regulate technology transfer between agents and the creation of incubators in the public domain; (iii) share equipment, infrastructure and personnel for technological development activities; and (iv) provide subsidies and funding for these activities.

32 Furthering Industrial Development in Brazil: Globalization and the national innovation system, June 2009, Dr. Mahrukh University of Hull UK

33 The Indian National Innovation System: historical perspective and key characteristics, 2023 Rituparna Kushik, Danilo Spinola

34 Evolution of NIS in China and India- from the perspective of the R&D Innovation Capability Xinxin Kongand Ye Xu, Institute of Developing Economies

35 Lee, K. (2013). Schumpeterian analysis of economic catch-up: Knowledge, path-creation, and the middle-income trap. Cambridge: Cambridge University Press.

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37 National-level Innovation in Africa Gayle Allard, Ph.D. IE Business School, Spain and Christopher Williams Durham University Business School, Durham, United Kingdom

38 The Innovation Systems of Latin America and the Caribbean of Latin America and the Caribbean By Alberto Melo Inter-American Development Bank,2001

39 Andersson, M., & Axelsson, T. (2016). Diversity of development paths and structural transformation in historical perspective—an introduction. In: Andersson, M., & Axelsson, T. (Eds.), Diverse development paths and structural transformation in the escape from poverty (pp. 3-17). Oxford: Oxford University Press;

Metcalfe, S., & Ramlogan, R. (2008). Innovation systems and the competitive process in developing economies. The Quarterly Review of Economics and Finance, 48(2), 433-446.

40 Harirchi, G., & Chaminade, C. (2014). User–producer interaction and the degree of novelty of innovations: A global perspective. World Development, 57, 19-31.

41 Ayres, R. U. (1996). Limits to the growth paradigm. Ecological Economics, 19(2),

42 Freeman, 1982; Dosi et al., 1988; Lundvall, B. Å. (1992). National systems of innovation: Towards a theory of innovation and interactive learning. London: Pinter Publishers; and Nelson, 1993

[43] Viotti, E. B. (2002). National learning systems: a new approach on technological change in late industrializing economies and evidences from the cases of Brazil and South Korea. Technological Forecasting and Social Change,

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Part II: Characteristics of the Pakistani Economy and Importance of Innovation for Pakistan

6. Overview of Pakistan's Economy

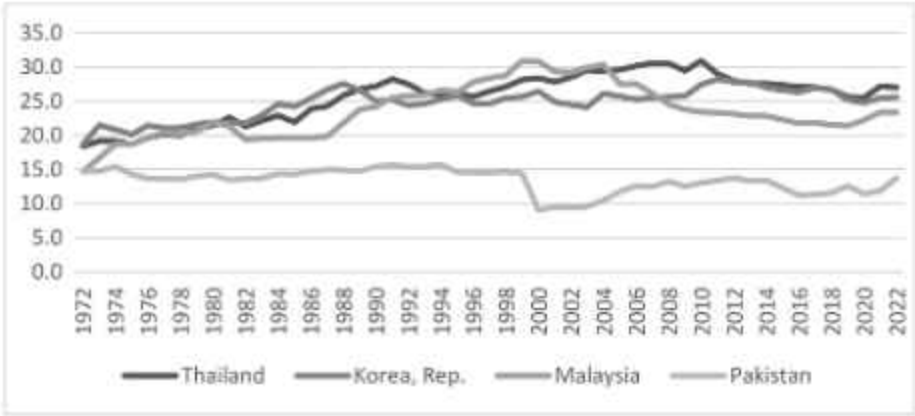
According to the 2017 census, the population of Pakistan was 207 million (Pakistan Bureau of Statistics, 2017). However, it is estimated to be around 244 million at present (April, 2024).[1] Currently, the annual growth rate of its population is 1.9% which is very high and not commensurate with its low average annual GDP growth rate of only 3.56 % since 2009 (World Bank, 2019b), growth rate of 0.3% ending June 2023 and projected 1.8 % in fiscal year 2024.[2] The bad shape of the Pakistani economy is also evident in its huge debt liabilities which stood at 74.3% of its GDP in 2023.[3] This debt liability is way greater than the prescribed limit of 60% of GDP envisaged under the Fiscal Responsibility and Debt Limitation Act of Pakistan 2005. The industrial or manufacturing sector of Pakistan has deteriorated over the years and at constant prices (2015-16). Its share in the GDP was only 18.47 % in 2023 while the agriculture sector contributed 22.91% towards Pakistan's GDP and service sectors about 58.61 % of the country's GDP (Pakistan Bureau of Statistics 2023). Due to the apathy of the state, Pakistan has lost international competitive advantage even in its traditionally strong industries such as textiles, leather, and surgical instruments.

Owing to a weak and fragile industrial sector, Pakistan has also been for very long suffering from huge current account deficits as it has produced low value-added goods through which it could not fetch a premium in international markets. "We have been an import-oriented economy so far carrying forward trade deficits year after year," stated Mr. Tayyab Gandhi Chief Executive Officer (CEO) of Quality Textiles in his interview given in Karachi.

Pakistan has been unable to produce and export medium to high-tech manufactured goods and this has added to its balance of payment

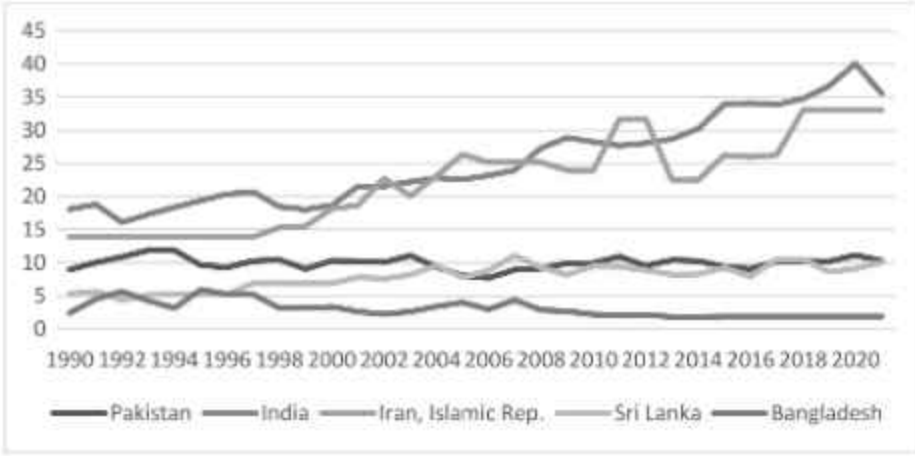
woes. Figure 3 shows a comparison of the percentage share of manufacturing in GDP (latest available data: 1972- 2022) while Figure 4 presents medium and high-tech exports of Pakistan compared with other regional economies in its neighborhood. Pakistan is a low performer and there is a huge room for improvement in this area.

Figure 3: Percentage Share of Manufacturing in GDP (1972-2022)



Source: World Bank Indicators 2024

Figure 4: Medium and High-Tech Exports (% of Manufactured Exports)

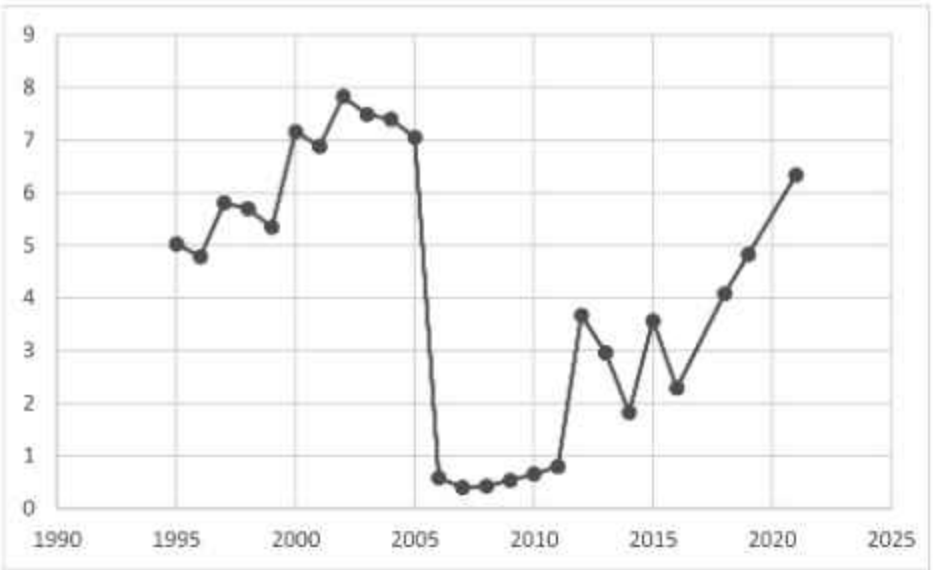


Source: World Bank Indicators 2024.

As a result, Pakistan has for the last several years remained a poor

performing economy where unemployment rates have gone up substantially. Figure 5 shows how the unemployment rates of the country since 1990.

Figure 5: Unemployment in Pakistan (% of Total Labor Force)



Source: World Bank Indicators 2024

As regards Pakistan's economic and development ranking, the following Table 2 shows the same on various indicators and indices from 1990 onwards.

Table 2: Economic & Development Ranking of Pakistan

Pakistan's Standing in the global ranking in various Indicators (01-the best)							
	1990	**1970**	**1980**	**2000**	**2010**	**2019**	**2022**
FDI	…	56	52	73	65	66	79
Exports	25th	48	59	61	70	66	65
Capital Investment	18th	34	48	45	57	51	47
Value Added Manufacturing	10th	16	26	47	48	41	35
HDI			101	137	145	139	161(2021)

Source: The global economy.com 2024

Given the poor shape of the Pakistani economy as depicted in the critical indicators discussed above, there is an urgent need backed by a deep realization and commitment at the highest level to effectively address the

underlying causes primarily responsible for the decades long neglect of science, technology, knowledge and learning and innovation and technological advancement. There are, at times, signs on the horizon that the top leadership of the country seems to have understood the importance of S&T and know-how and expertise essential to resuscitate the economy. While inaugurating a university in the north of Pakistan on 19 March 2021, the former Prime Minister lamented that Pakistan had committed a big mistake by not paying attention to technology and innovation.

The government of Pakistan, however, must act beyond rhetoric as a matter of priority, with sustained policy, institutional and programmatic interventions to consistently improve the S&T, innovation and industrial capacity of the country. The NIS concept can help it ascertain how it can facilitate innovation-led growth most effectively, identify deficiencies in the Pakistani IS and launch corrective actions to improve at an accelerated pace its functioning.

7. The Importance of Innovation for Pakistan

Innovation combines different existing ideas to do things in a new way. It is a knowledge based evolutionary process marked with uncertainty and disequilibrium. Knowledge and learning are fundamental for understanding the innovation process. Innovations are outcomes of interactive learning rather than the results of actions by individual entrepreneurs. They are typically the result of interactions between organizations and individuals with a diverse knowledge base and variety of skills. A strong assumption is that in any modern economy, interaction and collective entrepreneurship are more important than individual action for innovation. Innovation is indeed important for inclusive and sustainable economic development (Chaminade et al., 2018).[4] Firms and knowledge infrastructure play a key role in the innovation process to produce expected positive impact on economic development. A firm is regarded as the unit that introduces new ideas in the form of new processes, products, and services. Governments can also contribute by giving new direction to innovation processes through policy and regulations. Ordinary citizens too are important in the innovation process since they determine the diffusion and use of the innovation, reflecting how they judge if a new technology is socially acceptable or not. The variations in national economic performance or the transformation of economies into developed,

more inclusive or more sustainable societies, can thus be explained by their capacity to absorb and use novel ideas and technologies and their ability to develop new ones to enrich the world of innovations.

Some enterprises may contribute by introducing new products or radical innovations while others may introduce processes and products new to the firm or incremental innovations. A new product may make use of new technology and new skills on the supply side, it may require new skills on the demand side and finally, it may have a major economic impact when it is used in society. Freeman (1995, 2002) has applied techno-economic paradigms to understand how interrelated technologies open up windows of opportunity for national economies to catch-up and overcome the lead countries.[5] This implies that the country which hosts the emergence of a new pervasive technology will not necessarily end up as the lead economy. It is more important that the institutions in a country support the wide application and efficient use – diffusion of the technology. There are several examples where the most successful use and application of a new pervasive technology took place in a different country than the one that hosted its emergence. The experience of Nordic countries illustrates how small economies could become leading in terms of productivity despite hosting few major technological breakthroughs while recent developments in China show how it can become a leader in renewable energies despite not being one of the technological pioneers in that arena (Lema & Lema, 2012).[6] These examples clearly underline the importance of those institutions that support the absorption, diffusion and use of new technologies are extremely important to help a country catch up.

In case of Pakistan, there is an additional factor of crucial significance i.e., territorial security, defense and geo-strategic locus, which obliges the county to pay increasing attention to pursue science, technology and innovation-related activities to be able to safeguard its defense interests and capabilities, in the wake of hostile neighborhood. The section below gives a theoretical snapshot of the security dictate and its relevance for Pakistan IS.

8. The Security Dictate

Pakistan's performance and imperatives in the domains of STI can be explored through the lens of the theory of creative insecurity. This theory posits that the differences in the national innovation rates cannot be fully explained through a domestic focus and there is an external dimension to the variations in national competitiveness. Creative insecurity theory, therefore, brings into discussion both – domestic and external – factors for explaining the differences in national innovation rates and why some nations are better in S&T and innovation than others.

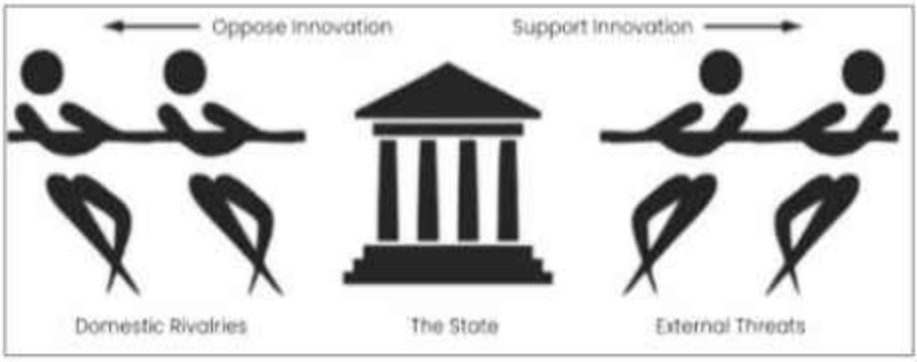
Taylor (2016), the originator of the theory of creative insecurity, after a comparative study of the differential in national innovation rates across several countries, argues that each country's balance of domestic rivalries and external security concerns directly influences and impacts its innovation rate while conceding that national innovation rate is also a function of country's technological capability.[7] However, the successful countries do not appear to share any commonly single best institution or policy design - each nation can design its S&T institutions and policies to best fit its own history, politics, and culture (Rodrik, 2007)[8].

The undeniable fact is that innovation and technological development are not just a random phenomenon which happens in a vacuum or on its own. It is contingent upon deliberate policy actions involving heavy and risky investment in human capital, materials, infrastructure and difficult trades off in the allocation of financial resources between immediacy of social sector needs and expected benefits in the future over an extended period with a long lag. It is also risky as it involves trade-offs in allocation of resources.

Another element of which the decision-makers need to keep themselves abreast is that emphasis on S&T and innovation requires a major shift in the national goals, priorities and structure of the economy which essentially entails strong political commitment to resolve domestic distributional politics and the likely conflicts amongst various interest

groups and actors over the costs and benefits of S&T development and innovation.[9] There are winners and losers. Those on the losing side make all efforts to block or manipulate institutions and policies to hamper innovations and discourage investors, entrepreneurs, and innovators to take the risk for innovation thereby squeezing the overall national innovation rate. The anti-innovation forces could however be counteracted by factoring in external economic and military threats to a nation which Taylor (2012) prescribes as "creative insecurity"[10] and which according to him explains the differential in the rate of innovation and S&T advancement of a country. His theory in fact goes much beyond Schumpeter's thesis[11] which characterizes innovation as a function of domestic forces and driven by a country's firms and entrepreneurs and instead argues that innovation is the outcome of interaction between the domestic and external forces. He states that creative insecurity is a state where the perception of external threats to a country are greater than its domestic rivalries and hence provides stimulus for acceleration of technological development and innovation. It "is the positive difference between the threats of economic or military competition from abroad and the dangers of political- economic rivalries at home" (Taylor, 2016, p. 13)[12] as captured in the Figure 6

Figure 6: Creative Insecurity Theory



Source: Taylor, 2016, p. 13

Creative insecurity theory thus motivates sustained support for S&T and innovation to keep external threats at bay. The greater creative insecurity is and the longer a country is faced with it, the more its citizens

seem willing to risk their political capital and resources on innovation.

This theory as propounded by Taylor is like bedrock and constitutes *raison de etre* for Pakistan to assiduously pursue the S&T and innovation development. More specifically:

- This is high time in view of the decadent socio-economic landscape of the country to decisively deal with the dysfunctions of distributional politics which hampers national innovation and technological development through several mechanisms e.g., tussle for resource allocation, status quo mindset of industry addicted to tax exemption and concession and heavy subsidies to prevent funding of competing S&T demands;

- Industrial upgrade and establishment of new industries is the sine qua non to competitively respond to the ever-rising market demands for "disruptive innovation" (Christensen, 1997)[13] and create wealth and employment opportunities for millions of youth entering the job market;

- Pakistan, because of its go-strategic position and some of the hostile countries especially India, has serious security concerns. The advancement of technological and innovative capabilities is essential to enhance the country's ability to safeguard its territorial security and interests internationally which can be significantly augmented and developed by cutting-edge S&T and innovation[14] (Lake, 2009; Prior, 2001; Dudley, 1991). This includes the acquisition of sophisticated weapons technologies and advanced capabilities in communications, transportation, and information processing and acquisition of the requisite skills and expertise to use and sustain advanced technologies effectively.

- On the economic front, the massive problems faced by the country have already been outlined in Part II. In order to address these challenges, the economy has to be resuscitated and become globally competitive to achieve autarky in the relatively competitive sectors

and earn the required foreign exchange to buy strategic imports such as energy, capital goods, raw materials and other goods in which it does not have the comparative advantage. The obsolete and inferior technology prevent the country to become competitive to boost exports and generate revenues to fund social sectors e.g., universal education and health coverage, especially to the poor. Climate change impact has to be curbed through the deployment of new adaptation and mitigation technologies in agriculture, industry, transport and building sectors. Besides, an internationally competitive high-tech sector can provide vital inputs for an advanced domestic defense industry to reduce dependence on foreign weapons for security.

- The external threats to territorial and economic security invariably raise the relative costs of technological stagnation while propelling the drive for technological advancement. The uncompetitive economy of Pakistan, besides witnessing capital flight, is also facing a large-scale exodus of skilled workers to the great disadvantage of the country. The innovative domestic industries could also offer a great opportunity to local investors and attract foreign direct investment and thus check the brain drain by providing the skilled workforce to pursue their career paths and professional growth[15] (Acemoglu & Autor, 2012; Goldin & Katz, 2008; Card & DiNardo, 2002).

However, while embarking on S&T and innovation initiatives particular attention may be paid to the following:

- The likely negative externalities generated by new technology like waste, pollution, dangers and new diseases needs to be upfront addressed to neutralize the possible impact and costs on society especially the lower social strata. This will also help resolve or mitigate the negative political opposition or resistance to hamper innovation;

- The broader policy and institutional framework need to be reformed to eliminate the possible threats and resistance to S&T e.g., Intellectual Property Rights (IPRs) as rivals may discourage new innovators; national programs supporting S&T may threaten the power base of sub-national and local governments, decentralization and devolution dependent administrative hierarchy of the state. There are, therefore, always some interest groups fighting against the S&T institutions and policies;

- The dividends of S&T and innovation especially the disruptive and radical ones within the country should be equitably distributed between various ethnic groups, geographic regions, economic classes or cultural groups to avoid political conflicts, domestic tensions, rivalries and sense of deprivation and exclusion.

In summary, innovation and technological development offer huge potential for Pakistan to establish a robust and well-functional NIS which is a prerequisite to be able to catch-up its economic lag, achieve equitable and sustainable economic development and counter external geo-economic and military threats and challenges looming large over the country.

The next Part III presents briefly the historical account of Pakistan's innovation and technology trajectory and many a vicissitudes it traversed to contextualize the framework for its innovation system.

Note

1 World Population Review, April 2024

2 World Bank publication "Pakistan Development Update April 2024: Fiscal Impact of the Federal State Owned Enterprises"

3 State Bank of Pakistan, Annual Report 2023

4 Chaminade, C., Lundvall, B. Å., & Haneef, S. (2018). Advanced introduction to national innovation systems. Cheltenham, UK , MA, USA: Edward Elgar.

5 Freeman, C. (1995). The 'National System of Innovation' in historical perspective. Cambridge Journal of economics, 19(1),

6 Lema, R., & Lema, A. (2012). Technology transfer? The rise of China and India in green technology sectors. Innovation and Development, 2(1),

[7] Taylor, M. Z. (2016). The politics of innovation: Why some countries are better than others at science and technology. New York, NY: Oxford University Press.

[8] Rodrik, D. (2007). One economics, many recipes: Globalization, institutions, and economic growth. Princeton, NJ: Princeton University Press.

[9] Scholars have observed that S&T progress creates winners and losers, and that the losers will resort to political resistance. Major contributions are by economists such as Mokyr (1990,1998), Acemoglu & Robinson (2012), Acemoglu (2009), Parente & Prescott (1994). In politicalscience, similar important arguments have been made by Solingen (2007a, 2007b), Haggard (1990), Haggard & Kaufman (1992), Drezner (2001), Doner (2009), Doner, Hicken & Ritchie (2009), Henisz (2002).

[10] Taylor, M. Z. (2012). Toward an international relations theory of national innovation rates. Security Studies, 21(1),

[11] Schumpeter (1942, p. 83, 84) wrote, "This process of Creative Destruction is the essential fact about capitalism: the fundamental impulse that sets and keeps the capitalist engine inmotion." He explained innovation as a "perennial gale" that incessantly transforms a country's economy from within by sweeping away old industries and creating new ones again and again.

[12] Taylor, M. Z. (2016). The politics of innovation: Why some countries are better than others at science and technology. New York, NY: Oxford University Press.

[13] Christensen, C. M. (1997). The innovator's dilemma: When new technologies cause great firms to fail. Boston, MA: Harvard Business School Press.

[14] Lake, D. A. (2009). Hierarchy in international relations. Ithaca, NY: Cornell University Press; Prior, R. (2001). Conflict, technology, and the impact of industrialization: The great war 1914-18. Journal of Strategic Studies, 24 (3); Dudley, L. M. (1991). The word and the sword: How techniques of information and violence have shaped our world. Cambridge, MA: Blackwell.

[15] Acemoglu, D., & Autor, D. (2012). What does human capital do? A review of Goldin and Katz's the race between education and technology. Journal of Economic Literature, 50(2); C. D., & Katz, L. F. (2008). The race between education and technology. Cambridge, MA: Harvard University Press; Card, D., & DiNardo, J. E. (2002). Skill-biased technological change and rising wage inequality: Some problems and puzzles. Journal of Labor Economics, 20(4)

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Part III: Pakistan's Innovation and Technology Saga

The S&T sector of Pakistan can be understood from the lens of the popular demand and supply framework in economics. The demand side of S&T in Pakistan includes industries, society, ministry of industries, and other federal and provincial ministries dealing with the industries. The S&T supply side can be classified into four broad categories as institutes for S&T policy and planning, institutes for S&T facilitation and governance, institutes for S&T teaching and technical works and institutes for S&T related testing and standardization.

While the demand side of S&T in Pakistan, over the years, has witnessed unsteady, variable and somewhat erratic orientation primarily due to a lack of conducive policy and institutional environment and low priority accorded to scientific and technological development by successive governments, on the S&T supply side, the country has since come a long way. At present, the country has around 244 universities approved by the Higher Education Commission comprising 99 private and 145 public universities,[1] around 300 R&D organizations in every major field; more than 100 policy study institutes; and 49 centers of excellence.[2] Pakistan also has a large base of industry from small to medium and large-scale organizations. It has a good road network, a very good canal irrigation system, diversity of climate zones, and availability of ample solar, wind and tidal sources of energy. The country is endowed with large quantities of untapped mineral reserves, a vast agricultural base, the highest mountain peaks, a serene coastal belt with a deep-sea port and a distinctive geo-strategic location. A young population with a median age of about 20.2 years,[3] cultural diversity and civilization of millennia are also blessed assets of Pakistan. It has a strong defense and is exporting its defense products to many developing countries of the world.

Pakistan does not seem to have, however, harnessed its full potential primarily because of a lack of commitment to or realization of

the need to promote scientific and technological development though some episodic and intermittent efforts were made to bring S&T to the national development agenda.

Given below is a succinct description of the state of S&T development in Pakistan in four distinctive periods i.e., the formative years and 1950s, the decade of 1960s, the period from 1970s to the end of the century, and, the turn of the millennium.

9. The Formative Years: Post-Independence Decade and 1950s

Pakistan, at the time of partition, inherited a scanty S&T infrastructure and human capital. It had no large industry and had only 34 factories with 26,400 workers or less than 7% in the territories comprising Pakistan.[4] It had one functioning University, three small laboratories and one Agriculture College Research Institute[5] and only a few dozens of scientists to work on the development of S&T sector program. Despite the dearth of technical and financial capital at the time of independence, the country performed exceedingly well in the formative years. It established its Patent Office in 1949, Cotton Committee in 1948, Food and Agriculture Research Council and the Council of Scientific and Industrial Research in 1949 as an attached department of the Ministry of Industries (This Council was made autonomous and renamed the Pakistan Council for Scientific and Industrial Research –PCSIR- in 1953).[6] Earlier the University Grants Commission was established to regulate policies, plans and initiatives for higher education institutions of the country.[7] Pakistan Standard Institute was established in 1951 (subsequently accorded statutory status in 1961). The Pakistan Medical Research Council and the Atomic Energy Research Council were set-up in 1953 and 1956 followed by the first National Commission on Science and Technology in 1959.[8]

Dr. Saleem uz Zaman Siddiqui, a globally known scientist and the first advisor to the Government of Pakistan on S&T indeed laid down solid S&T foundationsin the country during the first decade of 1950-1960. He was an entrepreneurial scientist who believed in the power of S&T for

economic growth of the country. He also envisioned the primary need of supply of technology to the industry. PCSIR, which he established played a significant role in the earlier industrialization in Pakistan.[9] The Planning Committee of PCSIR, recommended a network of multi-functional research laboratories and institutions. During the PCSIR first phase of development from 1953 to 1973, these laboratories commenced working in major cities and provincial headquarters to primarily engage in basic research in agriculture, energy, industrial, pharmaceutical and food sciences. PCSIR in early days of its existence also engaged in "Atoms for Peace" initiative and mobilized experts to engage in applying atomic energy to the needs of agriculture, medicine, and other peaceful activities. During the period, there were in fact six powerful research councils in the country which boosted IS. These councils were: (1) Pakistan Council for Science and Technology – a premier body to govern the IS of Pakistan; (2) Pakistan Council for Scientific and Industrial Research to supply technology to industry; (3) Pakistan Medical Research Council to regulate and govern healthcare advancements; (4) Pakistan Council for Research in Water Resources to govern the water planning and research; (5) Pakistan Atomic Energy Council for Nuclear Research; and (6) Food and Agriculture Research Council. The number of universities increased to 19 for higher education. Pakistan also set-up a Swiss Vocational Training Institute, established Pakistan Scientific and Technological Information Centre (PASTIC) to supply scientific literature; and developed Forestry Research Institute[10] (Naim, T., 2001). Three community related science bodies emerged as powerful S&T lobbying organizations namely: Pakistan Academy of Science, Scientific Society of Pakistan, and, Pakistan Association of Advancement in Sciences. Many top-level scientists served in these organizations, mobilized scientific communities and advised the Government to take appropriate measures. These organizations were very dynamic and contributed immensely towards S&T advancement in Pakistan. This period can, therefore, be termed as the S&T era of Dr. Saleem-uz-Zaman Siddiqui. There were some outstanding achievements from the perspective of S&T during that period e.g., green revolution with

wheat as the premier crop,[11] development of Basmati rice variety and NIAB cotton variety which led to food security and substantial economic gains.

On the industrial front, Batala Engineering Company (BECO) setup by CM Latif was a globally recognized engineering company which specialized in producing diesel engines and aircraft components and attracted visits by renowned foreign dignitaries (Figure 7). Many German and Japanese engineers used to work in BECO. Chinese Prime Minister Chou en Lai visited BECO in December 1956. He showed interest to send Chinese engineers to BECO for training.[12]

Figure 7: The Visits of Head of States to BECO Pakistan

Source: khan.wordpress.com

Pakistan also launched Five-Year Planning Programs in the 1950s with the aim to industrialize the country and bring technology to Pakistan through visionary projects like steel mills. Pakistan Industrial Development Corporation (PIDC) was established in 1952 to advance the industrialization of the country and facilitate industrial development.[13] PIDC imported many industrial plants and setup many industries in public sector. These plants were later copied and locally reproduced. This was an excellent example of technology adoption and diffusion in Pakistan in its early technology history. One striking example of this was the import of the modern rice processing plant by PIDC. The same plant was reverse-engineered and an entire industry of rice processing units emerged on GT

Road between Lahore and Gujranwala which later on spread to other parts of the country. During that period, the industrialization rate of Pakistan was very high and second only to Japan in Asia.[14]

This progress in the S&T sector was primarily owing to the political commitment of the government and the efforts of the dedicated leadership of its scientists. From 1953 to 1962, the manufacturing index of Pakistan grew at a much faster pace than any other Asian country except Japan. Pakistan's exports, GDP and many other development indicators were comparatively ahead of many countries at a similar level and stage of economic development.[15] Its five-year economic plans were emulated and followed by many countries e.g. China, South Korea, Singapore etc.[16]

10. The Golden Age: The 1960s Decade

The S&T decade of 1960s started under the scientific leadership of Dr. Abdus Salam (a Nobel Laureate), as Advisor on Science to the Government of Pakistan (1960-1974). Dr. Salam strengthened innovation system developed during the early 1950s[17] and further improved the S&T infrastructure to give a boost to industrialization and wealth generation in Pakistan. The economy sustained its ranking as highly competitive in Asia ahead of many counterparts. Pakistan International Airlines (PIA) emerged as a model airline and also helped establish new airlines[18] e.g., Dubai based airline "Emirates" for which PIA rented two aircraft and shared its expertise and advice later in the 1980s.

Dr. Salam was also instrumental in formulating the first S&T policy of Pakistan in 1960s. The National Commission for Science (NCS) headed by the Prime Minister was established (Hasham Cheema, 2018) as the key institution responsible for S&T policy formulation and advancement in the country.[19] The National Science Council, established in 1962 was tasked to advise the government and to co-ordinate the work of research organizations. 1963 witnessed the inception of Defense Science and Technology Organization (DESTO) while in 1964, Irrigation, Drainage and Flood Control Research Council and Council for Works and

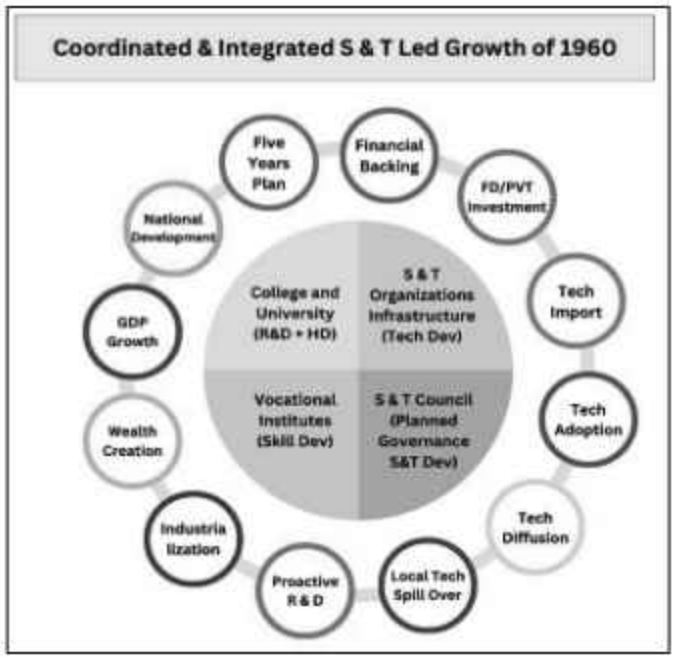
Housing Research were established. The Scientific and Technological Research Division, created the same year in the Federal Government was given the responsibility to oversee the implementation of national S&T policy. In 1965 the University of Agriculture at Faisalabad and the University of Engineering and Technology at Lahore came into being.[20] The period, 1960-1970 Pakistan was marked by concrete progress for establishing S&T infrastructure in which almost 150 R&D organizations and 19 universities became functional besides foundation of Pakistan Institute of Nuclear Science and Technology (PINSTECH) in 1963 as the premier R&D institution of the Pakistan Atomic Energy Commission (PAEC) and of the Centre for Mineral Exploration in 1961.[21] The agreement to develop a Pakistan steel mill was also signed in 1969. The second five-year plan accorded high priority to S&T advancements, industrialization, private investment and GDP growth. The financial and banking sector was strengthened and mobilized by the government to provide financial incentives and loans for encouraging private investment and industrialization through support for the expansion of existing industries and establishment of new industries. Later many other scientists notably Dr. Abdul Qadeer Khan, Prof. Atta ur Rehman and Prof. Wolfgang played a significant role in framing Pakistan's S&T landscape, especially in nuclear technology advancement. Figure 8 captures the enabling landscape for the S&T growth during the period.

This productive landscape helped mobilize private investment to bring foreign technology to Pakistan. Local S&T infrastructure was built to utilize the technology spillovers and diffusion. With significant investment in S&T infrastructure and a strong linkage with industry, Pakistan developed an exemplary S&T model with a very active and interactive role of colleges and universities for research and human resource development; S&T organizations for technology development; vocational skills development institutions; and S&T Councils to plan and govern S&T advancements.

Succinctly, the speed of advancement of any innovation system

depends on S&T supply as well as its demand. Pakistan experienced a rise in both aspects during the decades of 1950s and 1960s. The five year plans emphasized on both parts of innovation system and the country gained a momentum in growth. The era of the 1950s & 1960s was the golden period of integrated S&T development and economic growth of Pakistan

Figure 8: S&T Led Growth



11. The Decadent S&T Landscape: 1970s to The End of The Century

There were sporadic efforts by the state for S&T related developments in the post 1970 period. The scientists remained in close liaison with the government and received due attention and modicum of funding for their R&D endeavors. The nationalization policy of the 1972 however, stifled industrial development and industrialization of the country and led to capital flight, blocked technology import, hindered employment creation, and hurt the morale of the business community. During the six years of Bhutto's rule, in all 31 key industrial firms, 13 Banks, more than 12 insurance companies, 10 shipping units and 2

petroleum companies were nationalized.[22] (list of nationalized industries is at Annex II).

Consequently, the demand for S&T nosedived in Pakistan which led to a steady decline and disconnect between S&T and industry and technological and economic development. The government, the industries, and the S&T sector worked in silos and survived though marked by inability to incentivize startups, supply new products, and improve the systems and processes of existing industry.

Contrarily on the supply side, the government created Ministry of Science and Technology (MOST) in 1972 and placed 14 research organizations under its administrative control. MOST prepared the first draft Science and Technology policy in 1976 though it was approved by Government in 1984. Pakistan also established Science Foundation in 1973. The year 1976 was also significant for the country in terms of engaging with China on science and technology related activities (13 protocols involving more than 250 cooperation activities were implemented). National institute of electronics was established in 1979. Nuclear Institute for Agriculture and Biology and Metal Advisory Service (subsequently named in 1995 as Metal Industry Research and Development) were established in 1973 and 1975 respectively.[23]

The foundation of nuclear defense program was laid down and later spearheaded by the Atomic Energy Commission of the country. Centre for applied molecular biology (CAMB) and the National Commission for Science and Technology (NCST) were established in 1983 and 1984 respectively. In 1985, MOST initiated a Human Resource Development Program to create critical mass of high-level skilled workforce to train around 1000 young scientists and engineers. At the same time, the Scientific and Technological Development Corporation (STEDEC) was setup by the government to stimulate indigenous technological development and encourage local R&D institute through R&D fund to commercialize their processes and products. Despite significant increase in S&T funding in the Seventh Five Year Plan (1988-

93), from US$430.89 million in the Sixth Five Year Plan (1982-1987) to US$522.26 million, the rate of funds utilization was miserably low (15 % in the first three years).[24] During the same period, the innovation surveys and measurements of innovation activities conducted by Micheline Goedhuys of University of Antwerp Belgium revealed that Pakistan's share in world's authorship was just 0.04 %[25] which eloquently spoke of the poor S&T related performance of the country.

The decade of 1990s witnessed considerable expansion of the R&D infrastructure as by 1998, 32 universities and degree awarding institutes in public and private sector were developed including National University of Science and Technology (NUST 1991), Quaid-e-Azam University for post graduate research, nine center of excellence and 155 major R & D organizations (41% in the field of Agriculture). The decade also saw approval of National Technology Policy and Technology Action and Development Plan in 1994 and conclusion of four science and technology protocols with South Korea (1995) and 26 projects on science and technology with Kazakhstan (1996). Pakistan's share in world's authorship, however, remained very low at was 0.08 %in 1994.[26]

These efforts did not fructify to achieve the intended outcomes primarily owing to lack of effective implementation and oversight mechanism, prolonged political instability, nationalization of industries to the great detriment of technology base and technology demand, the social unrest during the later period of Bhutto's regime,[27] the toll of Afghan war and the ensuing terrorism. The S&T led growth was at best characterized by *ad hocism*, lack of focus and short-term objectives.[28] Successive political and non-political governments were unable to pay sustained, focused and dedicated attention towards S&T led growth further aggravated by governance dysfunction, corruption and erosion of the real value-added progress of the country.[29] The situation can be well gauged from the fact that as against two meetings of NCST in early 1960s, only two meetings were held in the next five decades i.e., by Prime Minister Benazir Bhutto in 1989 and by President Musharraf in 2000.[30] The

Governments during the period even failed to win back the trust of private sector to invest in manufacturing and large-scale companies, R&D and value addition and branding and innovation. The fate of nationalization of BECO- a global engineering company- and its demise continued to haunt and discourage private sector for investment in large manufacture units. Instead, commerce and trade industries have swollen with a focus on vending, formulation and packaging, assembly and supply of raw goods with very little processing, if any.

In nutshell, due to the absence of S&T demand and adoption and diffusion, the S&T sector became dormant and inactive though on the supply side, some significant new R&D organizations emerged, higher education institutions were established along with new laboratories. The scientific human capital was also developed including engineers and highly qualified professionals i.e., 15000 PhDs – half of them with foreign qualifications. There was also a substantial increase in the number of science journals due to the incentives for the researchers to publish. The S&T growth was, however, slow and lacked relevance, responsiveness and interaction with the local industry[31] and made negligible contribution towards economic development, poverty alleviation and improving country's competitiveness. The S&T graduates who joined the industries by and large failed to add to the innovation and technological advancement of the industry in the absence of the connection and link between the higher education system and industry and a shared vision for investment and technology diffusion programs responsive to the private sector needs. It may be noted that the S&T ecosystem is, inter alia, driven by the three essential components of technology regulations, technology development and technology facilitation. Pakistan invested in developing the scientific infrastructure for technology development to a large extent but technology facilitation and governance remained highly inefficient while technology regulations seem to have been largely ignored

The paucity of resources and financial allocation to S&T in the Government budget coupled with the low rate of utilization, further

brewed crisis of operational inefficiency of S&T organizations. They could hardly meet the salaries and operational expenditures out of their budgets to the neglect of core research budget and consequent inability to do experiments, develop prototypes and contribute towards industrial growth.[32] This sustained inefficiency of decades destroyed the culture of S&T organizations, demoralized the scientists, drained the talent and put the S&T sector on the verge of collapse. This period can, therefore, be described as the era of S&T quarantine and infertility.

12. The Positives and the Potential: The Turn of the Millennium

There are, however, some positive S&T developments since 2002. The establishment of the Higher Education Commission (HEC) was intended to give a boost to scientific and technological endeavor and to ensure quality higher education across the country and advance academics, research, innovation, and commercialization.[33] It set up the Pakistan Academy of Sciences and emphasized quality education rather than quantity. It made obligatory for all PhD thesis to be evaluated by eminent foreign scientists, arranged training of students abroad in leading universities for PhD and absorbed them on return. A tenure-track system was introduced as a mechanism for faculty accountability and reward for those who demonstrate excellence in teaching and research, with salaries two to three times higher than existing civil-service.[34] The Model University Ordinance i.e. the Federal Universities Ordinance 2002, was promulgated to lay down the governance parameters and quality education mechanism for new universities.[35] The country also formulated its first IT policy and implementation strategy in 2000 and introduced a nationwide program for training information and communication technologies with the help of the private sector. A 15-year tax holiday was also approved to stimulate growth in IT business which registered phenomenal growth from US$30 million in 2001 to over US$3.5 billion and expect to grow a further 100 % in the next two to four years to US$ 7 billion[4].There has since been substantial progress in higher education, advancement in telecommunication, growth of the financial and banking sector and defense technologies though food, water, social, health and economic

security of the country continues to remain vulnerable.

Pakistan's growth in scientific output can be seen from the fact that in 2000 Pakistan published 44 research publication per ten million while in 2020 the number rose to 1333 per ten million, more than 33 times increase. In contrast, India published 172 publications in 2000 and the number rose to 1193 in 2020, seven times increase.[36] The reforms, initiated by Prof. Atta-ur- Rahman former Minister of S&T in 2003-2008, seem to have continued over the subsequent decade and according to the Web of Science report, there was a 300% growth in research publications since 2010, with 2019 marking the first year in which Pakistan was ranked above the world average in research. Indeed, the global influence of Pakistan's research is increasing as scientists in the country are publishing more in top quartile journals especially in the last 10 years with a total of 66% Pakistan's scientific papers published in Journals with Impact Factor (JIF). The Category Normalized Citation Impact of Pakistan's publications (which measures publications' impact against their peers worldwide) has risen from 0.67 to 1.03 output in 2019. [37]

Pakistan has registered significant progress in the Information and Communication Technologies (ICTs) since independence when country had only 12,000 telephones for a population of 34 million.[38] The Telecom sector till the mid-eighties, was monopolized by the Government with telephone density less than 1%. The real breakthrough came in 1993 on the liberalization of the ICT sector and ensuing investment by the private sector. The establishment of Universal Service Fund (USF-contribution of 1.5% of the revenues by telecom providers with no government funding) in December 2006 aimed at providing coverage of the telecom revolution to the remote rural areas of Balochistan, rural Sindh and South Punjab.

It may be added indicates that for every 1% increase in a country's broadband penetration, Gross domestic Product (GDP) per capita increases roughly by 10% (Economic Study- QUALCOM 2009).

Pakistan, as of 2024, has 88% tele-density[39] with approximately 191 million cellular (79.51 &penetration rate), 132 million mobile broadband (3G/4G) with penetration rate of 54.82% and 135 million broadband subscribers comprising 56.2% penetration rate.[40] In an analysis of scientific research productivity of Pakistan, in comparison to Brazil, Russia, India and China, Thomson Reuters has applauded the developments that have since taken place as the country has emerged registering the highest increase in the percentage of highly cited papers in comparison to the "BRIC" countries.

Pakistan has also improved on ease of doing business index (improved 39 positions to rank at 108),[41] reduced smuggling, and offered lucrative incentives for investment. Technology and skills universities are also being established to develop technically sound labour.[42] The State Bank of Pakistan is facilitating businesses through policy of interest free and collateral free loans for startups and small businesses. Pakistan's exports are showing signs of a shift from export of raw goods to valued added products. Indeed, during the last two decades, there have been a few examples of foreign technology adoption and diffusion in Pakistan as follows:

- Telecom sector: President Musharraf, on assumption of power in 1999, showed a strong commitment to introduce IT and telecom revolution in Pakistan. He engaged the services of distinguished scientists and professionals (like Dr. Ata ur Rehman) to lead S&T transformation of Pakistan; established a conducive legal and policyframework and incentive structure to attract FDI in telecom sector giving the relevant companies a level playing field. Consequently, new companies in telecom, IT and broadband services entered into the Pakistani market and initiated a highly competitive culture. Internet and call charges were reduced significantly and mobile phone became a household product for everyone. This technology influx totally changed the IT landscape of Pakistan and made it current as per the digital age. A sub-sector

in the country's economy with billions of rupees was created offering millions of new jobs and business opportunities for investors. Higher education was oriented to ensure a steady supply of trained human resources for telecom sector including specialized telecom and software engineers. IT exports started from Pakistan during that period and have the potential to reach US$ 10-18 billion by 2028.[43] An ICT R&D Fund called Ignite was established to support technology development and entrepreneurship in IT and Telecom sectors of Pakistan. Ignite also launched National Incubation Centers to help IT and Telecom graduates enter into entrepreneurial ventures. The adoption and diffusion of mobile technologies led to substantial development and gains in the communications and financial sector

- The start of operations by Korean company Daewoo, with high quality standards and innovations, has changed the business models of the local transport companies and their services have also improved substantially.

- Pakistan Engineering Council reviewed the licensing policy of motorbike production and eased the licensing process. As a result, an entire new economy has emerged in the low-end motorbike sector along with technological influx into the country. Government however needs to incentivize further localization both to protect the existing investments and provide space to import new parts (*or technology)* for the newer models and promote the scale for higher engine displacement models with grace periods to allow companies to localize manufacture of the parts.[44]

- The financial and banking sector landscape has changed drastically and had profound impact on the development of financial system to attract and incentivize private investment. Financial deregulation, liberalization of financial sector to allow access by licensing private banks, privatization of state-owned banks (Muslim Commercial, Allied Bank of Pakistan) and development of technological

instruments, tools and services led to considerable improvement in the cost-efficiency, profitability, revenue performance and credit services to the clients.[45] At present there are around 31 banks in Pakistan- 5 in the public sector, 22 private banks and five foreign banks[46] though the role of the government through the national commercial banks, specialized credit institution and stringent regulatory measures of the State Bank especially in relation of foreign exchange and external relations continues to remain predominant.

- The liberalization of media sector in 2002 led to the substantial increase in private sector investment and the consequent deployment of new technology and innovation has revolutionized the whole media industry. Pakistan Electronic Media Regulatory Authority (PERMA) has been established to license TV channels and radio stations in the private sector. The boom in the media market, in just two decades witnessed a massive increase in the television channels though, simultaneously produced mega media moguls to influence the media function.[47] Currently, Pakistan has more than 149 Satellite TV channels,[48] 4983 cable operators, 34 landing channels e.g., BBC, CNN, Aljazeera etc., and 210 FM radio stations[49] to provide media and communication services like education, entertainment, news, awareness and advisory services.

These efforts, though laudable, have failed to generate or inspire a collective national realization at the policy level that the real potential for Pakistan to develop lies in according highest national priority to S&T and entrepreneurship, quality higher education and investment in its youth. The allocation to education is dismally low at 1.77 % of GDP in 2023-2024[50] while for S&T, on the average, it is around 0.3 % of the GDP. The cumulative impact of this woeful neglect of S&T is that Pakistan in 2022 ranked as one of the lowest performing economies from the perspective of competitiveness (110th out of 140 Countries)[51] and innovation (87th position among 132 countries).[52]

The S&T sector, thus, needs dynamic and proactive interventions and a conducive policy and regulatory framework to respond to the changes of a fast- moving world. Pakistan's S&T is stuck with the 18th and 19th Century linear model of S&T development. The competition and S&T trend in the world have moved from S&T creation to S&T application and diffusion in society. Pakistan needs a fundamental policy shift from science creation to application and usage of technologies for wealth generation, poverty reduction and catch-up for its sustainable growth.

The next Part IV provides a performance overview and assessment of the transformation trajectory of the indigenous industry in some selected sectors in pursuit of generation, adoption and diffusion of innovation and technology to be able to explore the potential for the policy adjustments that may be required to harmonize and accord with the emerging innovation and technology models and trends in the world.

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Part IV: The Performance of Indigenous Industry for Innovation and Technology Transformation –Selective Sectors

The industry of Pakistan is barely surviving at a very marginal growth rate, if at all. Historically, the industrial innovation system in Pakistan has been disconnected from local R&D institutions leading to technological lag of the industry, a high rate of inefficiency and low profitability in manufacturing. The investment shifts to the real estate and service sector are causing high unemployment. Pakistan's position on ease of doing business as per the latest report of 2020, stood at 108 out of 145 positions which in itself indicates the need to improve business conducive environment.[1] A small business encounters a layer of multitude of departments of cumbersome bureaucratic nature to operate and survive in business. There has been an increasing fragmentation in the regulatory frameworks as well as governance challenges pursuant to the 18th Amendment. There are five distinct regulatory regimes, with little coordination and often with overlapping jurisdictions and twelve different categories of general regulatory layers to be attended to by all firms doing business in Pakistan. Just by way of example, around fifty laws and numerous secondary regulations are applicable to the manufacturing sector in Pakistan, enforced by over forty national and subnational agencies and departments.[2] Despite this constraining environment, the industry though sub-optimally, managed to scout needed technologies from the global market, developed many technologies indigenously, and also reverse-engineered numerous plants and machinery. It played a significant role in import substitution and developed its innovation ecosystem to introduce new products and services albeit of low end. Around 80% of auto parts are manufactured in Pakistan for the automobile industry. The chemical industry has developed significantly over the years due to various factors including technological advancement, and regional integration,[3] introduced local products and substituted imported chemicals worth billions of rupees. Agriculture machinery, electronics, ceramics, textiles,

construction materials, light engineering products, and others are initially imported and then developed locally under the nascent indigenous industrial innovation system.

13. The Case of Rice Sector in Pakistan

The study of the rice sector in Pakistan presents a classic case of the indigenous industry making considerable strides in acquiring, developing and diffusing innovation and technology to retain its competitiveness in the global market. Rice Research Institute (RRI), Kala Shah Kaku, one of the oldest and premier agricultural research institutes of the country established in 1926, has introduced many world-renowned Basmati and non-basmati varieties. The rice Technology Laboratory of the Institute having ISO 17025 accreditation is responsible for rice grain quality analysis and moisture testing. The Institute is a pioneer in developing extra- long, delicious and aromatic rice (Basmati 370) and up till now has developed twenty-nine rice varieties. Twenty-two of these were developed after independence.[4] These varieties have since been commercialized by the industry.

In fact, the Pakistan rice sector was revolutionized by the import of Coarse Non-Basmati IRRI varieties in 1960s from the International Rice Research Institute Philippines. Basmati & its hybrid lines were developed by RRI. In 1988 RRI was successful in developing and releasing a new hybrid Basmati variety PK385 and in 1996 Super Basmati played a major role in Pakistan's Basmati export.[5]

As regards the export of rice, the actual breakthrough in the industry came after 1990 on deregulation of the rice trade by the Government of Pakistan which led to a massive export from US$ 125 million in 1988 to US$ 1100 million in 2012 an increase of 500 times in foreign exchange earnings. Currently, Pakistan is the fourth largest exporter of rice in the world[6] earning US$ 2.5 billion-plus from 3.8 million tons of export[7] and Pakistan's rice industry has become the 2nd highest foreign exchange industry from nowhere in 1995. This development

happened under a self-evolving industrial IS.

However, since 2006, India has overtaken the world of Basmati trade due to a new Non-Basmati variety C1121 (later on adopted as Basmati Hybrid variety by India), due to its extra length of 9mm[8] as compared to Super Basmati of Pakistan which is 7.20 mm.

There is indeed a huge potential for the rice sector to grow and achieve enormous productivity gains and for contribution to GDP provided the industrial IS and the supportive public policies environment accompanied by an appropriate incentive structure for innovation and technology generation is put in place. A comparative analysis of the rice sector of the two countries i.e., India and Pakistan in the succeeding section reveals the urgency of the need for the government to give impetus to and help rice industry maximize its potential.

a) Economic and Technology Challenges:

(i) Milling Recovery: Pakistan's Basmati milling recovery is 63% while exportable recovery is 40% compared to India's exportable rice recovery of 44% causing an economic loss of PKR 1.7 billion. Pakistan's Non-Basmati rice milling recovery is 64% and of India, it is 67% (Surjeet Basmati 1- High Yielding and salt tolerant paddy variety) with an economic loss of over PKR 2.5 billion annually. This is mainly because of inefficient milling machinery, untrained technical manpower and post- harvest losses (premature harvesting by growers). The distorted supply chain and inappropriate marketing techniques further aggravate the situation. The Pakistani rice growers, consequently, are paid less for the paddy thus depriving them of billions of rupees.

(ii) Varietal Decline: The rice industry has been suffering due to deteriorating Basmati varieties for many years. The main export of the country has been Super Basmati which was approved in 1996. Since then, though the RRI has developed more than a dozen

varieties, it did not produce competitive high-yielding, short-duration, disease resistant, and extra length rice varieties. India, on the other hand, has developed 21 new Basmati and hybrid varieties in the last 20 years, out of which 7 have successfully been adopted by the growers. In Pakistan, only one Basmati variety has been approved (PK 515) and that too has not been adopted by growers.

(iii) ***Exports:*** In 2000 Pakistan was almost equal in the quantity of Basmati export with India but due to new varieties developed in India and better milling techniques, its share of global Basmati export reached 80—85% while Pakistan's Basmati export share dropped to only 15-20%. However, Pakistan's export is anticipated to reach 5 million tons, a considerable jump from last FY's 3.7 million tons.[9] Comparatively, India which recorded 5 million ton worth of rice exports in 2020, and 11.5% surge to 4.9 million tons in 2023 securing US5.4 billion in rice exports, now witnesses a drop in Basmati exports due to a host of reasons (Reduction in Iranian imports, high level of minimum export price set by India, price competitiveness of Pakistan rice price due to currency depreciation).[10]

(iv) ***Seed*:** In the Non-Basmati sector, 60% of the export is IRRI 6 which was imported from the Philippines in the 1960s and 20% share belongs to Chinese hybrid seed. Pakistani-developed Non-Basmati varieties contribute only 20%. Pakistan Government registered an Indian variety C1121 with the name of PS 2 locally known as "Kainat" which itself speaks of the state of the indigenous rice technology and variety development in the country and reliance on the foreign varieties. Currently, 60% of basmati cultivation is based on Indian seeds. Non- basmati varieties are already of foreign origin. No new varieties are reportedly expected in the next 4-5 years to support the rice growers or businesses in Pakistan.

(v) ***Yield:*** Super Basmati of Pakistan gives 3.2 tons average yield per acre (rice report 2021-22/hbl) while Indian yield of C1121 is 4.5 tons

per acre (National Innovation Foundation India). For Non-Basmati, Pakistan's yield is 50 tons while the Indian yield is 60 tons per acre. Pakistan is currently sowing 11 varieties in the field out of which 5 mostly cultivated are of foreign origin. India has 40 varieties to cultivate and most of them are outperforming Pakistan. Out of total rice production of 6.9 million tons, 30% (2 million tons) goes to Pakistani varieties and 70% (4.9 million tons) goes to foreign varieties. In terms of earnings, the Pakistan rice industry earns US$ 600 million from Pakistani varieties and over US$1400 million from foreign varieties.

(vi) ***Processing and Engineering:*** Pakistan has 5000+ rice processing plants. Around 500 are imported and 4500 are locally made based on the Chinese and Indian plant designs. The rice machinery industry itself tried to copy the imported design substituting PKR 12 billion through local machinery manufacturing. Around PKR 15 billion (60%) share still goes to foreign markets in rice engineering. Pakistan spends PKR 1000 million annually on the import of rubber and abrasive rolls and more than PKR 240 million on the import of color sorters and silos for the storage of rice. There is almost no contribution from the engineering institutions and universities to support the rice processing industry of the country.

b) Regaining the Supremacy in the Rice Sector

(i) ***The Rice Sector Innovation System:*** There seems to be a total disconnect between the rice industry and rice-related S&T/academic institutions. The weak IS in the rice sector not only prevents the maximization of the export potential but also increases its foreign dependency. The sector also lacks basic fundamentals to develop a robust IS. The rice research system needs to be strengthened and synergized for the economic revival and global competitiveness of the sector. The priority areas of focus should be;

- varietal and breeding research for better varieties;
- engineering research and technology for better milling with the

capacity to develop 90% local machinery and local components of high precision and quality;

- management and marketing for better branding;
- restructuring and strengthening of rice-related laboratories for testing up to accreditation and certification level;
- restructuring TEVTA for certified technicians for rice engineering and agriculture implements manufacture.

There is indeed a huge endogenous potential to boost the rice sector and optimize rice exports through innovation and technology related interventions. First or foremost is to benefit from the R&D capability in the defense sector and commercialize it to improve and/or develop high precision and quality technology on rice milling and processing. Secondly, the government may establish a dedicated PKR 2 billion R&D funding for rice technology; award post-graduate scholarships for rice projects in collaboration with the industry; and establish rice-related centers of excellence (particularly engineering, processing and breeding). It should also strengthen Intellectual Property Regime including related justice and enforcement systems for breeders and innovators. Pakistan thus could achieve a rice export target of at least USD 5 billion in the coming years. This should be accompanied by fiscal and incentive measures including financing at 2% - 5% for new plants with new technologies in the rice sector; zero import duty for initial 3 years for new plants and technologies; 50% sales tax reduction on sales of new plants and technologies for initial 2-3 years.

Thirdly, one window operation for all government facilities in conjunction with the rice related association should be instituted as a priority institutional support mechanism. Fourthly, the country needs to mobilize the embassies and foreign mission abroad far above the "business as usual" approach to promote marketing of Pakistani rice. The ambassadors, commercial attaches and the related staff must be trained to successfully explore and tap export opportunities and arrange for appropriate technology transfer. The foreign office desk dedicated to support exports should also be strengthened to play its role for the growth

of the rice sector.

Finally, Pakistan should maximize the potential offered by BRI and CPEC connectivity to competitively export rice, become a part of rice value and supply chain and strengthen international collaborations for rice variety and rice engineering technology transfer.

14. Imports Dependent Sectors

Pakistan produced a record of around 14.5 million bales of cotton in 2004-05 (primarily due to innovation by scientists of the Nuclear Institute for Agriculture and Biology) which dwindled down to 9 million bales in 2019-20[11] and further reduced to 8 million bales in the ensuing years. It does not have a policy to protect innovations of plant breeders and variety developers. The scientists and the institutions are not entitled to royalty or reward. The lack of an S&T policy for intellectual property stifles the spirit of innovation in Pakistan in the agriculture sector. Therefore, Pakistan is left behind in agriculture innovation in every aspect. It imports high value agriculture machinery ($31.8 million), crop varieties, pesticides, fertilizers, seeds, and other value-added products which amount to around US$2 billion.[12] It also imports flowers and herbs to produce medicines. Pakistan's food security is at risk due to a lack of S&T policy initiatives, low S&T investment, and the least priority attached to the S&T development by successive governments till today.

In the health sector also, Pakistan is dependent on the import of most of its basic Active Pharmaceutical Ingredients (API) for drugs and pharmaceuticals notably from India, China and Germany. It is the 3rd largest importer of pharmaceuticals in the World[13] and spent US$3.78 billion during 2021 (UN Comtrade). Disruption in imports from any of the major suppliers invariably leads to shortages and a high medicine cost. Similarly, the country lags far behind in providing health solutions and quality healthcare to its citizens. This is primarily due to a lack of investment in S&T of medicine. The new age of drugs is emerging around microbiology, biotechnology, marine biology, and synthetic biology. Pakistan, therefore, needs to enact a comprehensive health related S&T

framework in the area of biological science, technology, and industrial production to be able to produce running drugs, save foreign reserves of billions and catch up and embrace the next waves of health technology. The country should also harness the health tourism potential and develop 1-2 medical specializations to attract patients from all over the world. This will, a priori, require substantial investment in the science and research efforts of universities and medical schools.

Another area of improvement in the health sector is the preventive and community health related R&D to develop technological solutions to reduce Pakistani citizens' vulnerability to disease attacks. This shift in focus from cure to prevention and promotion of a healthy lifestyle in public will also relieve the huge budgetary pressure on the exchequer.

15. The Automotive Sector

The automotive industry in Pakistan is one of the fastest-growing Industries[14] which has passed through many vicissitudes starting from independence in 1947 to the assembly of trucks, nationalization of the industry, introduction of the private sector and manufacture of tractors and assembly of motor cycles. This was also complemented by installation of private sector automobile assembly plants and the establishment of vendor industry; and finally leading to the exports. The industry registered a phenomenal growth of 171% between just 2014 and 2018. At present, there are 144 automobile units in Pakistan including 3 car manufacturers, 8 tractor units, 10 units for production of trucks/buses, 2 jeeps manufacturing units, 8 Pickup/Van producing units and 113 units for 2/3 wheelers.[15] The industry employs 1.8 million people and accounts for 2.8% - 3% of the National GDP with around PKR. 50 billion revenue generation. The automotive imports stand at US$78.5 million.[16]

Automobiles specially the cars were introduced to the sub-continent as far back as 1897 which were imported directly for the rich elite and senior civil servants especially belonging to the British Indian Civil Service. In 1945, however, Mahindra Brothers under license from Willys, USA, installed an assembly plant for the production of CJ-3A Jeep followed soon by the manufacture of light commercial vehicles (LCVs)

and agricultural tractors.[17]

On independence in 1947, Pakistan inherited a very weak industrial base not to speak of the dearth of the automotive industry. The first automobile plant was established by the General Motors & Sales Co. in 1949[18] on an experimental basis which together with National Motors, Karachi produced the first car Vauxhall in 1953 and Bedford trucks followed by assembly of buses, light trucks and cars. In the same year, Exide Pakistan also began the production of car batteries. In view of the rising demand and rapid growth, other foreign investors showed keen interest to penetrate the Pakistani market. Ford, USA started producing Ford Anglia, Ford pickups, and the Ford Kombi in partnership with the local entrepreneurs Ali Automobiles while Haroon Industries in collaboration with Dodge Motors set up an assembly plant for Chrysler's Dodge cars in 1956.[19] At the same time, Allwin Engineering introduced precision auto parts to the Pakistani auto market in 1961 followed by Kandawalla Industries assemblage of American motor products especially CJ 5, CJ 6, and CJ 7 series Jeep from 1962. The year also witnessed the partnership of Italian company Lambretta with Wazir Ali Engineering for the production of the Lambretta TV200 scooter. Raja Auto Cars introduced the famous Vespa scooter and rickshaw in 1964. General Tyre, Karachi started its tyre production operations in 1963 to cater to the local market. The Hye Sons embarked on the production of Mack Trucks the same year.[20] Production of tractors was launched in 1964 by Rana Tractors which introduced famous Massey Ferguson Tractors to respond to the growing demand for modernization and mechanization of agriculture. In 1965, Jaffer and Mannoo Industries launched their respective automobile/parts manufacturing operations. Earlier in 1963, General Motors plant was sold to Ghandhara Industries Limited and was granted permission in 1966 for the progressive manufacture of Bedford trucks and buses. It is to be noted, however, that all the automobile plants were restricted to semi-knocked down units (SKD) and only had assembly operations.

The nationalization of automobile companies under the Economic Reform Order 1972 and the consequent establishment of the Pakistan Automobile Corporation (PACO) proved extremely detrimental to the huge potential of growth of the sector. Through merger and acquisition,

the private units were renamed and restructured e.g., Wazir Ali Engineering became Sindh Engineering, Ali Autos as Awami Autos, Haroon Industries as Republic Motors, Ghandara Motors as National Motors, Hye Sons as Mack Trucks, Kandawala Industries as Naya Daur Motors, Jaffer Industries as Trailer Development Corporation, and Rana Tractors as Millat Tractors. While the pace of growth and acquisition of technology received a great setback, the sector continued steadily expanding in view of the progressively rising local demand. Yamaha motorcycles were introduced in 1974 while Beta Engineering started producing diesel engines. In 1976, Sindh Engineering launched Suzuki motorcycles followed by Kawasaki motorcycles in 1977. Naya Daur Motors ventured into the manufacture of Suzuki jeep. In the 1980s, the production base was enlarged to locally produce pick-ups, trucks and tractors e.g., Awami Motors introduced Suzuki pickups in 1980; Sindh Engineering Mazda trucks; and Fiat along with Al-Ghazi Tractors Ltd, began producing tractors in 1983. Similarly, local production of auto parts also gained momentum during 1982. The next year, the Vendor Development and Technical Cell (VDTC) was formed to provide impetus to further development of the industry. Joint Ventures were also encouraged by the government which led to collaboration between Hinopak Motors and PACO (1986) and Al-Futtaim Group, Hino Motors, & TTC (1987) and Ghandhara and Nissan began for vehicles and diesel trucks production. In view of the rapid and progressive development of the associated auto parts manufacturing sector, the Pakistan Association of Auto Parts & Accessories Manufacturers was established in 1989. Though the steady progression of the industry continued, it could not achieve optimal functionality because of high regulatory control up until early 1990s.

Following deregulation, there was an immense boom in auto production, as nationalization was abandoned in favor of privatization. The foreign car manufacturers, in view of the relatively favorable investment environment (car financing, low rate of interest etc.) and rising demand, made significant investments in the sector. Japan was the first to purchase 40% of the shares of Pak Suzuki in 1991. The Indus Motors Company installed Toyota Corolla production plant in 1993 followed by Atlas Honda which started producing Honda Civic cars in 1994. The same year Pakistan Automotive Manufacturers Association (PAMA) was formed.

The Association of Pakistan Motorcycle Assemblers (APMA) was afterward established in 2001. PAMA plays important role in policy making process.[21]

The sector also witnessed a huge surge in the two-three-wheelers especially during 2001 to 2007 period with the installation of a number of assembly plants of motorbikes including Honda CD70, Suzuki, Yamaha etc., with production reaching around 2 million units by 2018 (Statista: Production Volumes of2/3 wheelers in Pakistan 2008-2019). During this period, local assembly of Daewoo buses and trucks under license from Daewoo Bus, South Korea and Tata Daewoo also started. The 2000s also saw the introduction of dual fuel options to run both on petrol and CNG, which is more affordable and cheaper than petrol in the country. The Auto Policies of 2016-21 and 2021-26 embodied a number of incentives to attract additional manufacturers beyond Honda, Toyota, and Suzuki. The policy provides, inter alia, tax incentives to automobile manufacturers and assemblers besides investment promotion (easy access to finance and government grants etc.) and promotes research and development through subsidies.[22]

The sector has still to go a long way to fully harness the potential for broad-based local manufacturing growth. The enabling framework for technology transfer and innovation including the policy, institutional, financial, technical know-how and sophisticated skill set continues to be the major impediment in achieving efficiency, competitiveness and productivity gains. There is also a dearth of appetite in the private sector to acquire the needed technology and innovation for new models, fuel efficiency and to increase the level of locally produced inputs (deletion) especially for the cars though there seems to be appreciable progress in the production of tractors, motorcycles and three-wheelers. Late deliveries and high premium payments even in the presence of substantial excess capacity seem to be widely prevalent practices along with the high prices of cars relevant to average household income.

Foreign competition is discouraged by policy and allows for small,

inefficient yet profitable domestic automobile producers. Government needs to further revisit especially its industrial and fiscal frameworks[23] and regulations in terms of incentivized taxation rate, access to credit at reasonable interest rate, rationalizing the market-based exchange rate and improving the incentive mechanism for establishing proper ancillary facilities for the design and development of tools, jigs and fixtures necessary for indigenization and localization process. It should also establish quality testing infrastructure and laboratories, and in particular play lead role in developing the linkage of the industry with university and research systems for promoting innovation and technology acquisition. Simultaneously, the private sector should focus on improving the supply chains, streamlining the existing fragmented and ad hoc components and parts' manufacturing facilities and strengthening the technical know-how and skills base.

16. The Defense Sector

A country needs to manage, equip and train its armed forces to achieve the highest level of military capability and scientific and technological sophistication to be able to efficaciously address the potential and real threats to its security and territorial integrity. S&T needs to be fully integrated into the strategy for defense in conjunction with industry, academia and even international partners to nurture national S&T enterprise and leverage it to enable the defence forces to constantly endeavor for a strategic advantage in highly contested and hostile geo-strategic environments. A secure, robust and reliable technological development and innovation pathways through science, technology and research synergy is imperative for the purpose.

Pakistan established the Defense Industry in 1951 under the Ministry of Defense Production to coordinate and harmonize the disjointed working of military production facilities.[24] Several other Defense Production Organizations have since emerged in the country in the wake of increasing geo-strategic dictates and hostile neighborhood environment especially, the ominous threat and hostility posed by India. These include:

Pakistan Ordnance Factory (POF), Heavy Mechanical Complex Taxila (HMC), Heavy Industries Complex Taxila (HIT), Pakistan Aeronautical Complex (PAC), National Radio and Telecom Corporation (NRTC), Karachi Shipyard and Engineering Works (KS&EW), Pakistan Naval Dockyard Karachi etc.[25] The Military Vehicle Research & Development Establishment (MVRDE), Rawalpindi, Armament Research and Development Establishment (ARDE), Rawalpindi, Global Industrial & Defence Solution (GIDS), Chaklala, Space and Upper Atmosphere Research Commission (SPARCO), Institute of Optronics, the National Engineering and Scientific Commission (NESCOM) are some of the major research and development entities engaged in research and development, manufacture, design and sale of defense hardware including missile and weapons systems supported by a number of private sector firms for production of defense equipment and military systems in Pakistan. Some of the important ones are:[26]

- Cavalier Group – a multi domain manufactures for military combat vehicles, ballistic protection units, system automation and cybersecurity etc.;[27]
- Daudsons Armoury for sporting arms, rifles and pistols to conform to the international standards for Pump Action shotguns and sophisticated airborne armaments and precision components;
- Global Industrial Defense Solutions for manufacturer of unmanned aerial vehicles -UAVs- offering medium range tactical vertical take-off and landing short-range, hand-launched (VTOL) systems;[28]
- Integrated Dynamics for production of various types of unmanned aerial vehicles;
- SATUMA for the development, design, and manufacture of UAVs for surveillance and other civilian applications; and
- SHIBLI for thermal imaging, binoculars and design and manufacturing of security systems.[29]

The Defense Science and Technology Organization (DESTO) established in 1963 needs a particular mention of the earlier effort to attain technological competitiveness through research and development in

defense vis-à-vis its hostile neighbor. The focus of its scientific and technical research and development effort is on weapons systems covering multiple disciplines, including aerodynamics, propulsion and propellants, and avionics.[30] It also undertook and experimented on the reverse engineering of foreign technology for defense purposes and over the years, DESTO R&D initiatives built indigenous expertise, inter alia, in electronics, computer-system, engineering, explosives, metallurgy, chemical and biological defense.

As is evident from above, the country has a vast network of defense industrial complex, infrastructure and know-how with the technological capability to produce a number of sophisticated military equipment including aircraft, unmanned aerial vehicles, heavy vehicles, missiles systems (for commercial satellite launching) and small arms etc. This expertise and capability, however, has not so far been fully harnessed to enrich and technologically develop the civilian industry.

17. Nuclear Technology

Pakistan launched a nuclear energy program in 1956 and consciously integrated nuclear developments as an integral part of the broader national narrative. This narrative was sustained and propelled further by the 1965 and 1971 India-Pakistan Wars. India's first nuclear weapon test in 1974 intensified the need and motivation for Pakistani to build the 'ultimate weapon'.[31] The resolve of the leadership to go nuclear is indicative from the averment which the then Prime Minister Zulfiqar Ali Bhutto in a press conference in 1974s forcefully made: "We will eat grass even go hungry but acquire nuclear technology".[32] He may have also been inspired by the eminent scientist of the United States of America (USA), Dr. V. Bush who is credited with giving impetus to S&T development in the USA. In his communication "Science- Endless Frontier" to the US President, he argued that the USA and its allies won World War II due to investment in science and better technology which gave the country a competitive edge on national security.

Pakistan had set up the Pakistan Atomic Energy Commission (PAEC) as early as 1956 to harness the potential for the development of nuclear energy within the country for peaceful purposes.[33] The Pakistan Institute for Nuclear Science and Technology (PINSTECH), Islamabad was also established to carry out research and development in the field. The first small research reactor "Pakistan Atomic Research Reactor-1" (PARR-1 with a capacity of 5-megawatt), was procured under the Atoms for Peace program in 1965. Pakistan signed the same year, an agreement with Canada for a larger safeguarded pressurized heavy water reactor, namely, the Karachi Nuclear Power Plant-1 (KANUPP-1).[34] Pakistan, apprehensive of India's nuclear venture, refused in 1968 to authenticate the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) and in response to the surprise nuclear test by India in 1974, PAEC embarked on developing the indigenous nuclear defense capability. Dr. A.Q. Khan Research Laboratories (KRL) formerly known as Kahuta Research Laboratory was also established in July 1976. PAEC pooled the expertise of DESTO and KRL in 1978 and started the work for the development of chemical explosive lenses, tampers, and triggering mechanized systems, necessary in the technology of the fission weapon which came to fruition in 1986 when the country developed the capability to sustain and expand its nuclear weapons stockpile. This capability was further enhanced by the installation and operation with Chinese assistance of a dedicated unsafeguarded 40-megawatt plutonium production reactor, Khushab-1 in early 1998.[35] Pakistan, at present, has developed a reasonably strong defense capability having nuclear technology and other competitive military capabilities. The country though is not a part of NPT nor seems to have formally articulated its Nuclear Doctrine, evidently pursues:[36] (a) commitment to restraint in the use of nuclear warheads; (b) maintenance of a minimum credible deterrence-small but effective nuclear force; (c) emphasis on stabilization of strategic deterrence in South Asia against all forms of aggression- an effective combination of conventional and strategic forces; and (d) option to use nuclear weapon first, if faced with existential threat.

There is, however, little realization that the innovation and technological development in the defense sector needs to be channelized to the civilian side to address massive challenges which the country faces such as food security, economic security, and social security. The military to civil flow of technology especially joint R&D effort and formally institutionalized linkages between military, academia, industry and government civil sector are almost non-existent. There is, however, a modicum of civil-military nexuses for civil services in health care, education, infrastructure and other civil applications involving conventional vendors.

The fast-growing countries have adopted the civil-military fusion model to develop national competitiveness. Pakistan needs to pay attention, develop policies, strengthen institutions, and pilot many projects of civil-military R&D to add a potential US$ 100 billion to the exports share. This nexus will also ensure the defense, food, social and economic security of Pakistan.

After having dwelt on, inter alia, the history of Pakistan's innovation and technology journey and the performance of some selected sectors and indigenous industries on the technology and innovation adoption and diffusion, the next Part V attempts to capture the potential for establishing a robust innovation system in the country.

Notes

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3 https://www.graana.com/blog/an-overview-of-the-chemical-industry-in-pakistan/2023

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[21] https://pama.org.pk/

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[23] The sector is governed by a number of international conventions and treaties but has implemented only one, the WTO's TRIMS which led to the abandonment of the deletion program by mid-2003. The domestic regulatory framework comprises: The Industrial Policy,1977; the Privatization Policy, 2000; the Trade Policies, 2009; the Finance Acts embodying the fiscal and tariff regime and the Statutory Rules and Orders (SROs) and the Customs General Orders (CGOs); The Auto Industry Development Program (AIDP); the Tariff Based Scheme (TBS); The Pakistan Standard Quality Control Authority (PSQCA); The National Environmental Quality Standards (NEQS); The Import Policy Order 2009 especially for imports of automotive products and import of second hand motor vehicles.

[24] https://depo.gov.pk/defence.php?page=08

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[27] https://cavalier-group.com/about/

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Part V: The Potential for Robust Innovation System in Pakistan

Economic growth and sustainable development in the highly competitive and globalized world hinges upon substantial and consistent advancement in knowledge, innovation and technology generation and dissemination. The economic transformation experience of several countries in East and Southeast Asia, particularly China, Taiwan, South Korea and Singapore has already established that focus on innovation and technology and related S&T infrastructure development coupled adroitly with imported technology helped them redesign and consolidate their IS. The local technical change and interactive learning through feedback mechanisms further accelerated the process for sustained and inclusive development gains.

Pakistan is facing huge challenges of poverty, economic instability and a bulging population of which 64 % comprises youth.[1] The country has lagged far behind in S&T sector. Time is ripe for Pakistan to adopt a similar approach and make rigorous and concerted efforts to catch up, enhance competitiveness, meet the development challenges and achieve sustainable growth. The success stories of these countries in South and South East Asia provide an excellent template to: (a) adapt and apply the IS concept to Pakistan – a low middle-income country; (b) empirically analyze and demonstrate the status and level of its IS; and, (c) propose a specific action framework from the policy perspective to help transition into a knowledge economy and become higher middle-income country.

18. Applying IS Framework and Approach to Pakistan: Learning from the World

As earlier emphasized, the IS framework and approach have proven to be a robust analytical and prescriptive tool to help the developing countries catch up with the economic development lag and transform the existing economy to knowledge and technology led-one. The unique

advantage of the IS framework is its inherent flexibility to adapt to country specific requirements fully cognizant of its state of policy landscape, institutional arrangements, degree of specialization and mode of innovation. This flexibility helps prescribe the set of context specific measures needed to improve STI performance of the country for sustainable economic growth and development. More specifically in case of Pakistan, the following components of the Framework seem materially relevant and suitable to apply and develop its S&T and innovation environment and establish a robust innovation and technology system for a smooth transition to a knowledge economy:

a) Broad Definition of IS Framework

While applying the IS framework, its broad definition as expounded by Freeman and Lundvall seems pertinent to fit the Pakistan context. Firstly, it stresses on knowledge as the most critical resource and learning as the most important process in the economy. Knowledge creation and dissemination is weak in Pakistan and the reasons for this state of affairs need to be fully understood. Secondly, unlike Nelson and Edquist who focused on just radical innovations, broad definition stresses on DUI and incremental innovation, its diffusion and effective use. Pakistan's stage of economic development and in particular its ranking on various competitiveness indices which is palpably reflective of its STI capabilities and the associated weaknesses, entail the use of lens of broad definition as an analytical framework with emphasis on incremental innovation. The major assumption is that Pakistan can progressively start its innovation journey by redesigning its NIS and indulging in incremental innovation by focusing on DUI rather than big and radical innovations. This is so in view of the enormous potential of the size and scale of industry in Pakistan where a large number of industries needs to absorb new technologies and innovations incrementally to exert a stronger impact on economic performance rather than few firms that undertake radical technological innovation. Thirdly, the use of broad definitions for analyses lead to developing the framework conditions for improved learning across

organizational borders through institutions engaged in knowledge generation and higher learning; promoting experience based learning and tacit knowledge; and diffusion of technologies. The establishment of these framework conditions in Pakistan is fundamentally imperative to develop a robust IS. Fourth, broad definition inspires a wider set of policies including industrial policy and policies related to competence building such as education and labor market. Its focus is on link between innovation and national aggregate performance germane for the overall well-functioning of the NIS and the ability to absorb, use and improvise knowledge and technology developed abroad. Last but not the least, broad definition includes formal and informal institutions shaping human resources and learning e.g., universities engaged in imparting competencies and skills. In the case of Pakistan, it is equally important to understand the role of informal institutions and traditional learning models as they are much more in number than formal institutions.

These aspects are of vital significance given the current level of competitiveness of the Pakistani economy[2] and will help guide the empirical investigation and analysis of the state of its knowledge and learning.

Apart from the broad definition, the investigation into Pakistan's STI landscape in the current circumstances through the lens of the overall IS conceptual framework is quite important for several reasons:

- First, Arocena & Sutz (1999)[3] have shown that IS for developing countries is an ex-ante concept as opposed to an ex-post concept for developed countries where institutions are working in a systematic manner. Moreover, any micro-innovative strengths existing in developing countries remain isolated and encapsulated due to a major deficit in the institutions relevant to innovation and diffusion.

- Second, political governance today remains largely localized at the level of nation-state. IS being a tested and established framework can produce insights on what kind of national policies need to be

framed and implemented for growth and increasing competitiveness of a country – a dimension on which Pakistan ranks very low.

- Third, as Sharif (2005)[4] has argued, IS is a focusing device and its purpose is to offer policy recommendations by understanding and analyzing any economy's IS. At a country's level, IS helps in identifying the political, social and economic institutions that influence innovation and also the extent and nature of the linkages among these institutions.

- Fourth, IS is a coherent and holistic approach as there are two intertwined dimensions to it i.e., descriptive and prescriptive. Sharif (2005) has delineated the salient features of these dimensions as shown in Table 3.

- Fifth IS is regarded as an analytical tool that not only helps enumerate the components of a specific IS and develops an understanding of the system that affects innovation but also prescribes the changes required for the scholars and policy-makers to understand how an economy functions, how innovations can be promoted and how contributions can be made to the economic growth of a country through the pursuit of innovation. This, therefore, helps conduct a thorough and detailed analysis of Pakistan's NIS in terms of its descriptive and prescriptive policy measures to set it on the path of sustainable economic growth and development.

- Sixth, there is a serious shortage of empirical studies on IS of Pakistan. There is an urgent need to generate the interest of scholars as well as practitioners in this neglected area.

Pakistan's industrial base continues to remain very weak. Not very long ago the major component of its GDP was agriculture. Recently service sector has become the largest component of its GDP while

industrial sector's contribution has considerably diminished in 2023 as earlier stated in Part II. In fact, in the entire 75-year history of the country, there is only one decade of 1960s when the country established some industries. There is no other significant period where industrialization was pursued by the government as a priority for economic growth of the country.

Table 3: Mutual Dimensions of the NIS Concept

	Descriptive Dimension	**Prescriptive Dimension**
What is done?	Components of the innovation system are enumerated	Analysis of the system's components carried out
Why is itdone?	To identify all factors influencing innovation	To investigate and analyze linkages including their nature and intensity between factors influencing innovation
What are the results?	Clear and more methodical understanding of the system that affects innovation	Policy recommendations for government and related agencies

Source: Sharif (2005)

Furthermore, the IS conceptual framework offers a knowledge and innovation-based perspective to measure international competition between nation-states. However, it is also important to understand that the modern global challenges are extremely complex and require new forms of collaboration and cooperation such as the Belt and Road Initiative (BRI) where lead countries could share their knowledge and technological and innovative capabilities with countries having weak ISs. Therefore, it is not only competition but also collaboration that will matter in finding solutions to intricate and complex policy problems such as sustainable and inclusive development.

19. Learning from the Success Stories

(i) Chinese Experience: IS perspective

The Belt and Road Initiative (BRI) - the largest global

development initiatives in history conceived as a 'win-win framework' - opens a vast array of opportunities for the BRI partner countries from the IS perspective to leverage Chinese collaboration to upgrade their weak and lagging innovation and technology systems. BRI will enable these countries to catch-up with technology, know-how and knowledge transfer. Pakistan is a long-standing ally of China and one of the biggest recipients of Chinese financial and technical assistance under BRI. The country needs to strengthen and develop its IS to be able to fully avail the benefits of the BRI framework for development, trade and financial flows and more importantly to ameliorate the living conditions of the people.

It is worthwhile to underscore here that the potential of the amalgam of the two development frameworks i.e., BRI and IS does not seem to have been investigated or studied. A pioneer attempt as such has been made by the authors to explore the potential and the linkage between the two for BRI to serve as knowledge corridor and harness the technology and knowledge dividends by the collaborating countries as China revives the old silk route. The aim is to integrate its markets with the rest of the world, consolidating the global production network and strengthening the regional value chains as a win-win solution.

China's journey to transform into knowledge and entrepreneurial economy is indeed very instructive and presents a dynamic and vigorous model for countries like Pakistan to benefit from. China was far behind Pakistan till mid 1980s in terms of its economic growth and widespread incidence of poverty, food insecurity and general state of deprivation of its citizens. China, in order to address the bourgeoning development challenges, espoused, inter alia, three major policy instruments primarily aimed at boosting its IS/ STI system. Firstly, it created a conducive policy environment and planning framework for harnessing the potential of technology generation and diffusion and innovation. Secondly, it totally transformed its higher education and university system during the post Cultural Revolution period. The 1978 National Science Conference and the subsequent educational reform policies of the 1980s emancipated the

universities and intellectuals from ideological–political struggles and paved the way for scholastic-scientific knowledge generation culture in the country. Thirdly, it created the connection and synergy between the university system and industry to facilitate industry driven research and technology development. The 1985 S&T system reforms made it incumbent upon the university faculty members, particularly those in the engineering schools and other applied disciplines, to work closely with the industry. The linkages included informal consulting of university researchers to industry, patent licensing, technology service contracts, joint research projects, university-based science parks, and university affiliated enterprises. China has now emerged on the world scene as an important knowledge producer with growing global economic significance essentially due to rapidly expanding role of Chinese higher education system in China's knowledge economy and the global knowledge society.[5] The Chinese higher education system has now the distinction of becoming globally the largest system with over 46.2 million registered university students in 2022.[6] The premier University of Science and Technology of China Hefei, Anhui, is ranked among the world's top 100 universities in terms of its academic ranking and the QS World University Rankings.[7] Regarding research output, according to the Nature Index 2022, this university ranks number 2 in China and the whole of Asia and the Oceania region while 5th in the world among the global universities after Harvard, Stanford, Massachusetts Institute of Technology (MIT), and University of California (UC). The Chinese experience of university-industry linkage and supporting an enabling environment for innovation and technology development and knowledge economy stand out in the immediate vicinity of Pakistan as a model to learn from and follow.

China Pakistan Economic Corridor (CPEC): CPEC unfolds a plethora of opportunities for Pakistan to learn from the Chinese experience and harness the potential for technological upgradation. There are, inter alia, three CPEC related dimensions which could facilitate and strengthen Pakistani IS namely: establishment of SEZs – a huge role which they play in the transfer and development of technology and innovation, CPEC as

knowledge and technology corridor, and, the immense prospects for Pakistani SMEs to become part of the global/regional supply chain and Global Production Networks (GNP) and concomitant advancement of technology and innovation.

Special Economic Zones (SEZs): China has invested heavily in establishing SEZs to achieve massive growth. SEZ is a geographic area, "within the territory of a country where economic activities of certain kinds are promoted by a set of policy instruments that are not generally applicable to the rest of the country"[8] SEZs promote firm interactions that increase productivity by building clusters or attracting technologically advanced industrial facilities.[9] Since the 1960s, SEZs, as development catalysts, helped many Asian countries especially the newly industrialized countries –Hong Kong, South Korea and Taiwan – in breaking away from import-substitution development strategy and pushing for export driven economic growth.

China's experience with the SEZs, since the rollout of its first SEZ in Shenzhen in 1979, has been very successful. In her empirical study, Wang (2013)[10] has shown the positive impact of SEZs on the local economies, earnings and livelihoods in China spurred by Chinese SEZ policy package, including private property rights protection, tax breaks and land use policy, which on average increased per capita foreign direct investment mainly in the shape of foreign-invested and export-oriented industrial enterprises. Wang's main findings were that the SEZs in China increased the total factor productivity – growth that is not explained by the increase in traditional factors of production like labor and capital. This is manifestly attributed to development, diffusion and adoption of technology through SZEs and spatially-targeted subsidies.

It may be added that the Chinese SEZs were smartly structured to include major economic sectors of the economy, educational activities, research and development (R&D), tourism, culture, entertainment and residence. Moreover, firms in these SEZs were encouraged to establish appropriate linkages with their counterparts in the rest of the domestic

economy, to foster technology transfers and promote growth through expanded economic links[11] (Ge, 1999).

The CPEC Long-term Plan (2017-2030),[12] envisages establishment of SEZs as a vital and important component. There are already several industrial and processing zones in Pakistan including the ones being established under CPEC framework: Karachi Export Processing Zone, Karachi, Sindh, Risalpur Export Processing Zone, Risalpur, Sialkot Export Processing Zone, Punjab, Gujranwala Export Processing Zone, Punjab, Khairpur Special Economic Zone, Sindh, Rashakai Economic Zone Mardan M1 Khyber Pakhtun Khawa (KPK), Gadoon Economic Zone Amazai Swabi KPK, Hathar Economic Zone Hathar Haripur KPK and Quaid e Azam Business Park Sheikhupura.[13] Additional SEZs are being set up namely: Rashakai SEZ Dhabeji, SEZ Bostan, SEZ Allama Iqbal Industrial city Faisalabad, ICT model Industrial Zone, Industrial Park Pakistan Steel Mills, Mirpur Industrial Zone, Mohmand Marble City and Moqpondass SEZ Gilgit Baltistan (GB). The rollout of these SEZs has started in January 2020 with the ground breaking of the first zone near Faisalabad. These zones are expected to help Pakistan leapfrog, industrialize and catch up to achieve sustainable economic growth and development. Presently, Pakistan's industrial base and national competitiveness are very weak and fragmented and the country urgently needs to enhance its manufacturing capabilities and become an export-oriented economy for overcoming its persistent trade account deficit. The IS conceptual framework could serve as a robust basis to benefit from China in the process of rollout of SEZs across Pakistan. The pace and direction of Pakistan's technological progress and economic growth would, however, be determined by the scale and depth of the interactions among firms within and outside the SEZs and other important STI actors in the Pakistani economy such as public research institutions, universities and government and the ability to leverage and absorb knowledge, know-how and technology from China.

As the SEZs become functional across Pakistan in the next few

years, relocation of low to medium-tech manufacturing industries from China to Pakistan is expected to take place in these zones, especially in sectors such as automotive, chemicals, electronics, light and medium engineering, pharmaceuticals etc. This would, a priori, require a stable and conducive policy and institutional environment in Pakistan.

CPEC as Knowledge Corridor and Pakistan's Integration with Global Supply-Value Chains and Production Networks: CPEC and SEZs proposed thereunder open up many possibilities for the Multi-National Companies (MNCs) and Chinese Industrial sector to establish Joint Ventures (JVs). Some JVs like that of Engro – a chemicals giant in Pakistan and relevant Chinese firms have already been put in place.[14] Several domestic Pakistani firms can also become part of China's Global Value Chains (GVC). The opportunities arising from these international industrial relocations and JVs need to be seized, though, in a timely manner for economic growth of Pakistan. For that, Pakistan must improve functioning of the IS and innovation capacity for capitalizing on the opportunities and developing firmer and solid industrial base with the help of knowledge, know-how and technology transfer and expertise developed in China. Pakistan will also become an integral part of GVC and GPN for export-oriented economy. This will enable the country to overcome the gigantic challenges to its economy – low growth, unemployment and trade account deficit.

The MNCs invariably attract foreign direct investment (FDI) which in turn, if prudently utilized, spurs innovation in the country and help it catch up. The analysis of Ireland (O'Malley et al., 2008)[15] and Singapore (Wong & Singh, 2008)[16] illustrates the role played by FDI and MNCs in the development of their respective NISs. Sharif & Baark (2008) have also discussed the importance of linkages with the Chinese market for the development of the IS of Hong Kong.[17] Pakistan on the same lines has got this great opportunity to improve and develop its IS and innovative capabilities through CPEC's various components, especially industrial cooperation.

Historically, as a trusted ally, China has successfully shared the knowledge, technology and know-how with Pakistan as in the case of sectoral IS of defense where it has jointly built Pakistan state of the art fighter jets and tanks. But to fully avail the successful experience of China, there has to be a strong commitment at the highest echelons of the government as well as the private sector about the importance of industrialization and CPEC's role in integrating Pakistan's industrial sector with GVCs and GPNs. This huge potential, if tapped strategically, will increase export manifolds for eventual wealth creation and also revenue generation for distributive justice in terms of employment creation and poverty alleviation.

(ii) South Korean Innovation and Technology System: From Science to Technology and the Spill-over Synergy of Military-Civil Nexus

South Korea in the early 1960s, was a poor developing agrarian country, with meagre resources, scanty production base and a small domestic market entirely dependent upon foreign powers for national security. The S&T infrastructure comprised only two public S&T institutions: National Defense R&D Institute and the Korea Atomic Energy Research Institute with total R&D investment in 1964 of US$5 million.[18]

President Park Chung-hee, a military dictator turned politician began the economic reforms in 1961 to build Korea as a prosperous country through massive industrialization.[19] The first five- year economic plan was launched in 1962 for the developing county's industrial base.[20] The Korea Institute of Science and Technology (KIST) was established in 1966 and the Ministry of Science and Technology a year later to, inter alia, pursue two key objectives: namely inward transfer of foreign technologies and developing the domestic absorptive capacity to assimilate and improvise the acquired technologies through reverse engineering, original equipment manufacturing (OEM), and foreign licensing of worker training.[21]

President Park Chung-hee also emphasized the role of education that could contribute to the needs of industry and develop the necessary technologies. The education system of Korea suffered from a plethora of inadequacies almost similar to Pakistan. South Korea through USAID, sought assistance of MIT/Stanford University team to help create within country capacity to educate scientists and engineers who would work for the nation's industrialization; and to conduct innovative research that would drive the nation's economic growth. The team proposed establishment of Korea Advanced Institute of Science and Technology (KAIST) for the Korean S&T transformation which put the country on a high economic growth trajectory for several subsequent decades and streamlined the governance system for S&T development.[22] The model adopted for the governance and management of science and technology, inspired by MIT and Stanford University is given in Figure 9.

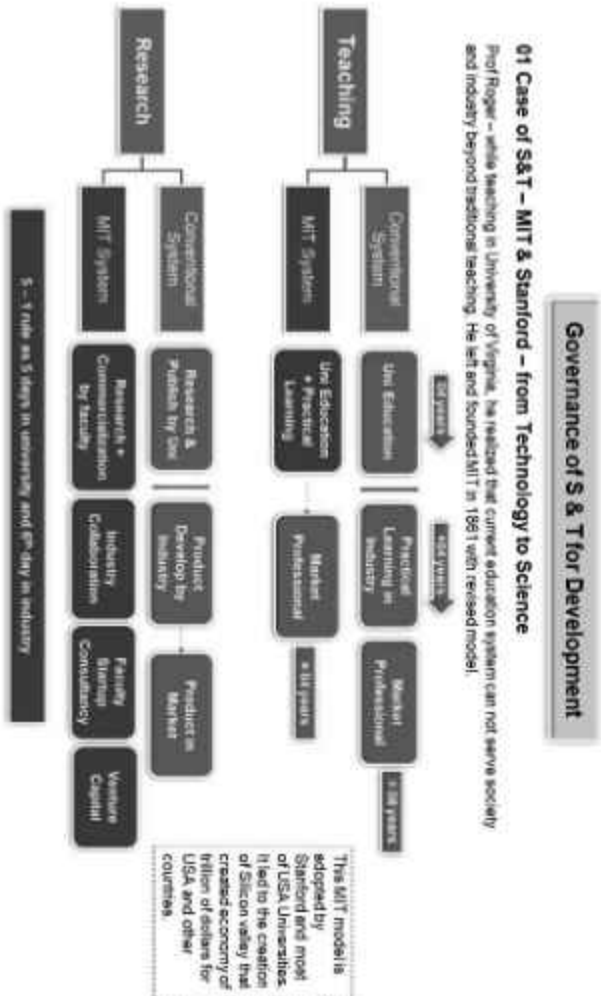
The triple helix dynamics of policy and institutional frameworks developed by the government for giving initial impetus to the rapid technological development and progress of South Korea, strategic alliance between governments (initially military governments) and private sector and university research institutions nurtured and encouraged a thriving culture of market-oriented innovation.[23] This was accompanied by sustained and massive investments in human resource development and R&D and private sector competitiveness to build South Korea's unique innovation system.

The military reforms of 1970s to modernize the military kick started the South Korea's domestic defense industry which concurrently paved the way for the industrialization of South Korea and boosted its massive economic growth.

The technological gains achieved in the defense sector and to meet its defense requirement, South Korea committed huge investment during 1972-76 period to develop its own heavy and chemical industries through the Heavy and Chemical Industry Development Plan 1973 to achieve

autarky in defense and spur industrialization and exports.[24] Apart from the defense capabilities, the major thrust of the plan was to diversify into shipbuilding, automobiles, steel products, machinery, non-ferrous metals, textiles and petrochemicals.[25] All this was accomplished by a number of economic and military-related reforms to help the defense industry including the establishment of the Agency for Defense Development (ADD), the Special Law on the Promotion of the Defense Industry, and the National Investment Fund and Yulgok Plan in 1974.

Figure 9: Governance of S & T for Development



South Korea also established a special investment and funding mechanism (e.g., The Defense Industrial Promotion Fund in 1980 subsequently dissolved in 2006) to incentivize heavy, chemical and defense industries and encourage indigenous arms production and procurement for its military. At the same time special focus was placed on developing the indigenous R&D capability through National R&D Program in 1982 and fiscal and export-oriented reforms to encourage private sector R&D activities, export competitiveness and human capital formation. This blend of economic and defense policy for industrialization led to the country's rapid economic growth and industrialization[26] and by 1981, South Korea's defense industry was already diversified to stimulate heavy industries, electronics and especially shipbuilding.

However, between the late 1980s to early 1990s, South Korea witnessed far-reaching changes from within the country in terms of transition from military dictatorship to democracy as well as in the external environment shaped by the end of the Cold War, Soviet Union dismemberment and Germany's unification. These changes led to an enhanced thrust to and focus on the civilian industrial sector which apart from sustaining the momentum of economic growth started supporting the defense sector especially the aerospace and avionics and conventional equipment and weaponry. Korean Air was even contracted by the U.S. Air Force to handle maintenance of their fleet of F-4, F-15, A-10, and C-130 aircraft stationed in South Korea, Japan and the Philippines. The industry contributed massively to the production of vehicles, modern tanks, artillery and helicopters for its military as from 1990 for example, Hyundai Precision produced tanks, Samsung Techwin produced licensed built American M109 howitzer dubbed the K55; KIA Machine Tool manufactured the 105 mm KH- 178 and 155 mm KH-179 towed howitzer; Samsung Aerospace manufactured UH-60 helicopters.[27] Innovation and technology thus steadily and smoothly shifted as priority ventures from military to the private sector especially as the civilian oversight of the military and security apparatus became more robust and stronger. The successive reforms and interventions by the democratically elected

governments of the defense forces particularly in 1998 and 2005, in view of the constant threat of the hostile external environment created a strong nexus between the civil and military effort to establish technologically advanced, cutting-edge and information-based sophisticated military capability. This in turn culminated in a huge surge in the industry connected with the manufacture of new weapons and equipment to meet these demands especially in the wake of post 2010 rising Chinese militarization,resurgence of Russian military activities and ominous threat from North Korea.[28]

The private sector both in the defense and non-defense sectors has evolved over the years in sustaining the technology and innovation based growth of South Korea. The government which in early 1960s, assumed the key role in fostering economic and technological development through setting priority policy goals and direction for industry and integrating R&D in the development programs, is now confined to use more indirect means largely as a facilitator and promoter to gain the momentum for technological development and innovation. The private industrial sector has grown and become more robust. It now plays the lead role in conjunction with the academia and research institutions to invest in R&D to be able to achieve its competitive edge in a highly globalized environment. Currently, the National Science and Technology Council (NSTC), the apex body is chaired by the President to provide strategic policy direction of S&T policy and priorities for government R&D investment. The Office of Science and Technology Innovation (OSTI), which was established in 2004 within the Ministry of Science and Technology (MOST), ensures adequate budgetary allocation to implement S&T priorities set by the NSTC. At the same time, as from the 1990s, other ministries have also started their respective R&D programs within their mandated areas e.g., the Ministry of Commerce, Industry and Energy is engaged in the Industrial Base Technology Development Program and the Alternative Energy Development Program, the Ministry of Information and Communication in the Information and Communications Technology Development Program etc. By 2010, the country had already established

105 regional innovation centers, 18 techno-parks and 7 federal programmes to promote competitiveness and innovation[29]

South Korea indeed presents an exemplary amalgam and partnership between defense/military and private sector mediated and facilitated by the governments, corporations, and research institutions to create a flourishing culture of knowledge creation, technological development and innovation.

(iii) The Massachusetts Institute of Technology (MIT) Model

Massachusetts Institute of Technology (MIT), established in 1861 as a privately managed educational institution of higher learning in the US is devoted to advancing scientific, technological and technical training and research scholarship. The focus of the Institute is to continue developing and investing in science and technology infrastructure to build the human capital and the research and development tradition essential to explore, investigate and find the solutions for addressing, inter alia, the social, economic and developmental challenges which mankind faces presently and, in the times, to come. The MIT was essentially planned to introduce and practice a knowledge-university-technology led economic growth model in the industrial sector as a means to national progress and prosperity. The Institute soon emerged as an entrepreneurial and innovative university model having a strong linkage with industry and society which led and massively contributed to the industrial growth of the country. It espoused four distinct innovative characteristics of the entrepreneurial university: (i) students' involvement in practical learning, (ii) incentive for the faculty for linkage with field/industry through 5-1 rule (five days in university and one day in industry),
(iii) encouraging consultancy assignments and start-up for the faculty, (iv) providing venture capital for faculty startups.[30]

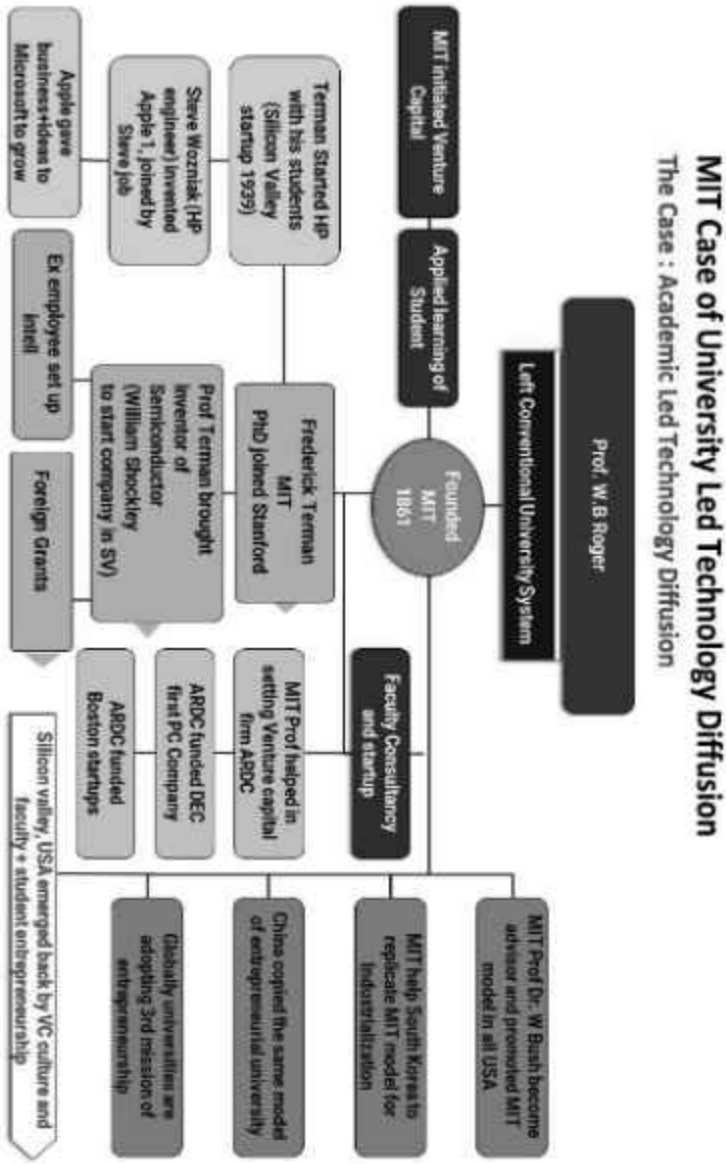
The MIT indeed presents an exemplary case for technological advancement and catch-up for developing countries. The innovative approach comprising above described four characteristics brought about a

radical transformation of the traditional engagement of the University in R&D and accelerated the generation and diffusion of technology. Notable examples are the emergence of Silicon Valley- Apple, Micro-soft, Intell, Fairchild semi-conductors etc. Many countries of the world including China benefited from this model. Figure 10 captures the essence of MIT technology diffusion model.

The rise of the MIT model inspired the US military to forge partnerships with universities for R&D and technological advancements, especially after World War 1. It embarked on defensive and offensive technological drives to combat possible World War 2 and for the purpose launched various research programs in the universities to develop technologies for military use.

In due course, MIT acquired great repute and expertise in developing various military research projects. MIT scientists would take research grants from the military very frequently and supply reliable technologies. President Franklin D. Roosevelt was advised to pick Dr. Wannevar Bush as director of the Office of Scientific Research and Development (OSRD) from MIT to lead the Manhattan Project to develop and deploy the world's first atomic weapons. This assignment made MIT an innovation center for military technology needs which led to a regular collaboration between the two. Dr. Bush, being a successful innovator and leader for the nuclear project, became a success symbol of academic entrepreneurship.

Figure 10: MIT Case of University Led Technology Diffusion



Many other MIT professors served defense sector as scientists, as heads of projects, and as part of the military R&D team. Professor J. C. R. Licklider of MIT also led the SAGE project (Semi-Automatic Ground Environment) to develop computer-assisted air defense during the Cold War. Dr. Lick worked on many military research projects and served in the defense sector. He sponsored many research projects in the universities

as Director of Defense Advanced Research Projects Agency (DARPA). He envisioned computer networking and provided conceptual grounds for the development of the internet. He is known as the initiator and originator of internet ideas and concepts who headed the Advanced Research Projects Agency Network (ARPANET) project as a predecessor of the internet. In fact, wartime emergencies invariably led to opportunities for the scientists of advanced research to convert and blend their research into generation of useful military technologies.[31] Etzkowitz averred: "These were undertaken at the behest of academic scientists who saw, on the on hand, the potential to develop advanced weaponry through the application of science to military problems (radar) and, on the other, the outcome of theoretical advance (the atomic bomb). University–government relations transcended the wartime emergency as academics realized that theoretical advance could arise from problem-oriented research as well as vice-versa".

The increased civil-military scientific interaction significantly enhanced the technological capability of the US military and made it the most advanced military in the world. The US defense exports also created new opportunities for wealth creation and an increase in the GDP. This amalgam of civil-military nexus thus not only made the US a superpower in the world with unbeatable defense but also the leading economy in the world. It also established the global credentials and best practices to pursue a development paradigm based on knowledge, technical know-how, science and technology.

(iv) The Import- Driven Technology Diffusion

The level of economic integration in the wake of globalization has already assumed unprecedented proportions. This has led to enormous interdependence of countries for technology transfer which takes place whenever technology investments by entrepreneurs in one country generate technology spillovers to producers in other countries. International market transactions serve as a major channel for such technology transfer and spillovers. However, the level of R&D investment has a direct bearing on technology import and assimilation and

productivity gain. It is estimated that a 10% increase in domestic R&D leads on average to around 1.5% higher productivity while the contribution of international technology transfer even exceeds the productivity gains compared to domestic R&D investment. A study on the world's technology transfer revealed that in the US, Japan, Germany, France, the UK, and Canada, about three times productivity gain was achieved through technology-embedded imports and international trade compared to domestic R&D. The global patterns of technology transfer impact is, however, highly asymmetric due, inter alia, to absorptive capacity of a country e.g., the impact of the US R&D on the UK productivity is twice as large as the US effect in Germany or Spain. Similarly, Canada is reported to benefit around 50% more from Japanese R&D and 33% more from French R&D than the average country and much more from the US R&D and spill over primarily because of geographic proximity.[32]

This pattern suggests that even the developed countries in the world like the UK, Canada, Japan and Germany made a start through the import and adoption of foreign technologies with a focus on learning their use, making some improvements, and then reverse-engineering. This was accompanied by major investment in domestic R&D, higher learning, education, and cutting- edge science and creation of necessary human capital and know-how capable of absorbing the imported technology, its improvisation and indigenization. Simultaneously, development and generation of new technology and innovation was given due emphasis. These multiple country experiences inform that a typical journey towards catch-up starts from technology imitation and enters the phase of inventions and new knowledge creation culminating in technological innovations. Pakistan, as such, can learn from these success stories and reorganize and improve the local S&T infrastructure and create technical human resources to back the technology import and adoption. The basic policy and institutional environment and infrastructure testing facilities, standard compliance and rule of law have to be put in place to attract foreign companies and investment.

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Part VI: Reshaping and Resuscitating Pakistan Innovation and Technology System (ITS): Evidence-Based Diagnostic and Prescriptive Approach

Pakistan needs to resuscitate, reignite and establish a robust innovation and technology system to be able to regain its competitiveness and move towards sustainable development and economic growth. For the purpose, it is important to learn about: (i) the status of Pakistan's existing Innovation and Technology System and describe and analyze the functioning of its various components; and (ii) uncover in-depth the details of the linkages among the major actors and entities engaged in knowledge and technology generation. This analysis could constitute solid basis for prescribing the remedial measures- policy and operational- for reshaping and establishing a robust IS for the country. In this connection, a rarely used mixed approach by blending qualitative and quantitative methods has been designed and applied to map and analyze the existing status of Pakistan's IS to be able to suggest the prescriptive model for implementation.

20. Rationale for the Mixed Approach

IS of a nation-state can be analyzed from various angles. For example, one can look at a nation's specific production structure and institutional setup from the perspective of economic history. Another way is to look at the links between input measures such as R&D and outputs such as patents or productivity of the economy. Yet another way is to look at networks using bibliometrics, patents or other data.[1] Freeman, Lundvall, and Nelson in the initial studies resorted to qualitative historical analyses of NISs and also used descriptive statistics in their seminal books, but their major aim was to offer detailed qualitative insights into how various ISs evolve and function. As such, the early works on ISs were rich in terms of descriptive statistics but were primarily qualitative. Qualitative analysis of

ISs is also a fundamental method to understand why ISs differ and how varied trajectories to ISs development could lead to the same outcome.[2] Later, as the IS approach became popular among policy-makers in the 1990s, the demand for quantitative indicators, drawn from national specificities, also increased to facilitate systematic comparison of ISs.

Both the qualitative and quantitative approaches have their merits and limitations. Rankings and simple quantitative studies tend to show the differences and similarities in the performances of nation-states according to certain specified indicators. In-depth qualitative analyses, on the other hand, provide insights into the functioning of ISs and differential in their trajectories. Then, important characteristics of ISs such as the linkages between various actors and the exchange of knowledge between them may not be measured quantitatively. There is also a risk of neglecting the aforementioned dimensions in theory and policy in view of the paucity of quantitative indicators. Each country has its own characteristics and context (population, size, income level, location, etc.) and the number of countries in the world which are engaged in IS implementation is not very large. To find general laws on the basis of just the statistics is, therefore, difficult. Combining qualitative and quantitative methods thus makes a compelling case for IS analysis. Further, a mixed-method research design for understanding the IS of a country can yield more positive results and deeper insights for scholars and practitioners than just deploying either the qualitative or quantitative method to the exclusion of the other.

Another strong justification for using a mixed-method approach is that many countries may rank similarly according to the quantitative indicators but may show stark differences in the way their ISs work. For example, Sweden and Denmark are ranked high in many benchmarking exercises like the Global Innovation Index (GII) or the European Innovation Scorecard (EIS) in terms of input and output indicators. However, the ISs of the two countries work very differently. Denmark's IS is dominated by small enterprises highly focused on incremental innovation and DUI modes.[3] On the other hand, Sweden's IS is governed

by large enterprises with a strong international profile and a strong reliance on research and development (R&D) and S&T based modes of learning.[4] Similarly, the comparison of ISs of Taiwan and South Korea reveals differences in their trajectories: an economic structure dominated by small firms in Taiwan and large conglomerates in South Korea with a proactive role of government while both tend to be ranked closely together in terms of innovation input and output.[5] The implication of these cases is clear and as such while analyzing the IS of a country, it is important to take into account a country's specific social, economic and political context.

More specifically, the deployment of a mixed approach by the authors blending a qualitative method (semi-structured in-depth interviews) with quantitative econometric model- has multiplicity of several advantages as described below:

- The grounded theory approach[6] which was followed for data collection uses the basic principles of questioning rather than measuring and generating hypotheses using theoretical coding. It allowed to ground and relate the responses of the interviews to generate a detailed description of their perspective on Pakistan ITS. These descriptions were then analyzed to yield sensitizing concepts articulating categories by which people understand their world. In addition, grounded theory approach helped develop the theoretical constructs derived from and grounded in the interviewee's understanding and knowledge of on Pakistan ITS.[7]

- The qualitative method combined with interviews for collecting diversity of data unraveled a variety of methodological options to choose from e.g., ethnography, participant observation, unstructured interviews, semi-structured interviews, discourse analysis, and textual analysis etc. The authors eventually chose in-depth semi-structured interviews for generating and collecting data.

- Qualitative orientation also exhibited great flexibility for data collection through formal in-depth semi-structured interviews and

informal in-depth conversations with individuals over a period from January 2019 till August 2020. The iterative process with several people across a broad spectrum of the society over one and a half years, facilitated testing and comparing different accounts and perspectives against each other to work out and validate the ones against subsequent verifiable events. The interviews on a one-off basis could have constrained the ability and probability to determine the veracity of many of the claims. This was further reinforced through a spread-out data collection process.

- From the perspective of subjective experiences and historical context, the qualitative method also proved to be quite useful for diagnostic and prescriptive purposes in light of the perspectives and insights of the interviewees on the overall S&T performance of Pakistan. This objective was easier to achieve through a qualitative approach based on the interviewee's response and their personal experiences.

- Policy or operational interventions based purely on the results of quantitative model and without a deep qualitative understanding of the Pakistani context could have been sub-optimal and suffer from rationality deficit.

Succinctly, therefore, the main benefits of this approach are its flexibility, focus on subjective experience and historical context as well as an objective understanding of Pakistan ITS, its main components and the weakest links. It may be reiterated that the majority of the existing studies employing the IS approach have used the qualitative approach with very few using the quantitative models. The use of mixed-method approach, as such, signifies a pioneering effort in the IS discourse and scholarship.

21. Evidence-Based Analytical Framework

While the widely acknowledged IS approach and conceptual framework served as the kernel of the modus operandi for collecting and analyzing the data, building the hypothesis and testing it quantitatively, the

mixed method approach comprised two components: (a) qualitative analysis through interviews, consultations and meetings; and (b) an econometric model to conduct the quantitative analysis.

(a) The Qualitative Analysis

The qualitative analysis comprised in all eighty semi-structured interviews across a broad range of stakeholders to gather deeply held perceptions about Pakistan's Innovation and Technology System. Setting the interview questions was, however, challenging as majority of the interviewees were at top positions in the industry, academia, politics, non-profit sector, government and military. Due to their long experiences and senior positions within their domains and spheres of influence, many interviewees sometimes went off topic and initiated tangential discussions. It was with great difficulty at times to refer them back to the guiding questions for a focused discussion.

Some informal in-depth conversations for data collection were also conducted at various conferences and meetings held in Pakistan, the UK and Kazakhstan. These conversations were unstructured and unscheduled and were penned down afterward. The insights gained in the process on many relevant dimensions were further explored and validated in greater detail to reach robust conclusions.[8]

The eighty interviewees provided some detailed insights into the S&T landscape of Pakistan as they invariably had a reasonable understanding of the importance of technology and innovation for Pakistan's growth and the associated issues and challenges confronting the S&T domain. Figure 11 shows the cloud of the thirty most occurring words in the transcripts of the interviews with the words 'technology' and 'innovation' appearing 266 and 199 times respectively. Technology was the 11th most frequently used word and innovation was the 15th most frequently used word by the interviewees.

The qualitative data collected by the interviews was analyzed to

generate a hypothesis about Pakistan ITS which was subsequently examined by building a quantitative time series econometric model to gain a better understanding and propose a practically implementable set of recommendations.

Figure 11: Word Cloud of the Thirty most Occurring Words in the Interview Transcripts

(b) Quantitative Analysis

The quantitative data for the regression model to test the hypothesis on Pakistan ITS was derived from information and data obtained from various government agencies in Pakistan, published sources and websites of national and international agencies such as the Ministry of Science and Technology (Pakistan), Ministry of Finance (Pakistan), Ministry of Commerce (Pakistan), The World Bank, the United Nations Industrial Development Organization and the United Nations Educational, Scientific and Cultural Organization. The time series regression model was used to identify the main areas of weakness in Pakistan ITS. Cumulatively, through this process an effort was made to portray a vivid picture of Pakistan ITS and develop an execution plan to establish, strengthen and enhance its performance. This would also help policy-makers formulate and pursue an innovation and technology policy for improving the productivity of the country and laying the foundation for the knowledge economy. There is growing empirical evidence that shows the positive link and impact between innovative activity and economic growth.[9] The

performance of the various actors of the NIS and the linkages amongthem can eventually affect the performance of a country (growth, job creation, competitiveness) via its national innovation capacity.

An econometric model (details in Annex I), was thus constructed and used to describe and test the relationship between different variables related to innovation and the economic growth of Pakistan. The model involved multiple linear regressions with the aim of identifying and evaluating the relative impact of the state of Pakistani ITS on the economic growth. For constructing the model, time series data (1990-2019) was used on the relevant variables reflecting innovation capacity and GDP per capita of Pakistan. To enhance the internal validity of the model and reduce the effects of confounders, a couple of control variables that have the potential to influence the economic growth were included– number of patents granted annually by the IPO in Pakistan and a number of scientific and technical journal articles published yearly by the Pakistani researchers.

It may also be underscored that the simplest and quickest way to map the NIS of any country is through statistical data on the key input and output indicators of innovation. Various indicators of innovation can identify, for the policy-makers of any country, the areas which need intervention for strengthening their NIS and consequently improving economic performance.

22. The Analysis of Existing State of IS in Pakistan

The major actors in the NIS of Pakistan for the qualitative mapping and qualitative analysis include private sector firms and enterprises (various industries) bureaucracy and politicians (government), the knowledge infrastructure (universities and institutions of higher education particularly related to STEM including private and public institutions) and the military technology and innovation entities.

These actors were engaged and their performance was appraised within the framework, based on the mixed-method and IS concept adapted

from Freeman and Lundvall, for diagnostic and prescriptive analysis. The blend and equal attention to quantitative indicators and the qualitative probe provided deep insights to holistically capture the essence of the inner working mechanisms and the processes occurring in the Pakistan ITS.

The major features, findings and conclusions by applying the above analytical approach as regards the relevant actors and their linkages, if any, in Pakistan ITS emerged as follows:

(i) Government

The government plays a key role in the development of NIS in a country which in the case of Pakistan has been extremely poor both in terms of enabling policy environment and institutional support. There has been a conspicuous fragmentation of the policy and institutional processes and paucity of resource allocation to advance S&T, innovation and competitiveness agenda which, as it were, is characterized by confusion and *ad hocism.*[10]

While government's various recent growth strategies emphasize the role of innovation in improving productivity and growth, very little is being practically done to foster innovation in the country especially in the industrial sector to generate employment and achieve desired levels of economic growth in the coming years. International experiences of countries like China, South Korea, Singapore, etc., suggest that a well calibrated STI policy, as adopted in these countries, can be very helpful in driving up the growth rates in Pakistan as well. As opposed to Pakistan, improvements in innovation capabilities in recent years in emerging economies such as Brazil, Russia, China, India and South Africa have been quite good and contributed to the overall growth of these countries.[11]

Since independence from the British in 1947, just three S&T policies have been formulated in the country but regrettably lacked effective implementation. The first S&T Policy of 1984 remained as the guiding framework on paper. It acknowledged the criticality of S&T for economic growth and the periodic evaluation which unfortunately did not

happen. The second National Science, Technology and Innovation (STI) Policy was promulgated in 2012 after a yawning gap of 28 years which also lacked implementation because of the absence of government's commitment, low budgetary allocation, and lack of monitoring mechanism. Thereafter, in 2021 federal cabinet approved the third Science, Technology and Innovation Policy, to exploit the potential in this sector, use it as a pillar for international diplomacy and enable Pakistan to embark on modern approaches to STI governance. While all the successive governments expressed high level of priority to S&T, in reality the subject has been relegated to periphery all along in the national development without making any significant headway except some episodic interventions. This lackadaisical effort on the part of various governments spanning over several decades, clearly shows the extremely low importance attached to S&T and its advancement in the country. "It is a hopeless situation. The main reason for this is that there is no right person for the right job. Moreover, resourceful institutions are not there which can support, strengthen, and enhance STI in Pakistan," remarked Dr. Shahzad Alam, Chairman of PCSIR – an apex institution for S&T in Pakistan – during the interview given in Islamabad. "I had a meeting with the Federal Secretary of S&T. I told him that environment in Pakistan is simply not conducive for S&T," revealed Mr. Siddique-ur-Rehman Rana, Chief Executive of Technology Exchange and Coordination (Pvt) Ltd in his interview. A full-fledged Ministry of Science and Technology (MOST) exists at the Federal level which is mandated to provide leadership but the majority of the key S&T agencies working under the MOST lack competent HR and finance and allocate a very small amount out of their meagre resources towards encouraging technological advancement and innovation in Pakistan. There are about 14 institutions, mostly autonomous, working under MOST but majority of them are operating in their spheres and directions without any synergistic approach under the umbrella of MOST. They do not consult MOST on scientific and technical dimensions, R&D, inputs/outputs to S&T, patents, intellectual property rights, etc. Mr. Habib Ullah, Senior Joint Secretary at the MOST was very

candid in his interview when he said, "This Ministry [MOST] is the least priority of the government." Dr. Tahir Izhar of the University of Engineering and Technology (UET), Lahore, remarked in his interview, "A policy change for S&T is direly needed in the country for progress and growth. The present conditions for S&T are bad." The then Federal Minister of S&T, Mr. Fawad Chaudhary also conceded, "MOST has remained for very long a neglected Ministry in Pakistan, and we need to prioritize it if we really want long term development in Pakistan." Moreover, the majority of high- level positions are occupied by the generalists to the relegation of the technical experts which has adversely affected the performance of the Ministry.

The government's resource allocation and policy measures for R&D have also been minimal and ineffective. "An insignificant amount is allocated to R&D in Pakistan," said Mr. Hamid Yaqoob Sheikh, a very senior bureaucrat and Secretary of the Finance Department of the government of Punjab. The R&D budget of the government of Pakistan for the year 2019-2020 was merely 0.24% of the GDP. One striking example of the adverse impact of this low budgetary allocation is that Pakistan's sports and surgical instruments sectors were once the leading industries of the world but have suffered immensely due to the apathy of the government and lack of support for R&D from it.

"Government policies are unclear and there is not much assistance from it for R&D," were the views of Mr. Awais Jehangir, Director of Kicker Sports, Sialkot – a leading manufacturer of soccer balls in the country. Syed Zulfiqar Ali Shah, Director of Burraq Surgical Corporation, Sialkot observed: "There is absolutely no government research support for our sector." Mr. Farooq Adeel, Directing Staff at the National School of Public Policy remarked, "It is very unfortunate to see that in my more than twenty years' career, I have seen so many bureaucrats getting trained at the National School of Public Policy but there has never been a debate about importance of STI for Pakistan and promoting a culture of R&D in the country."

The number of fiscal and financial incentives for stimulating industries' demand for investments in technology development are also very few. Most of the firms, interviewed during the course of the research work, did not have any knowledge of the availability of these incentives. In such a scenario, it is hard to think of any effort by the private firms to improve their S&T capabilities.

The lack of a coherent and robust policy framework for attracting foreign investors has also been a major constraint in the technological development and technology catch-up pursuits of the country. There are many examples in the world such as Singapore and Israel where governments executed prudent policies to attract foreign firms for eventual technology transfer and technological advancements of their local partners. "Successively, all the past governments have failed us. State has focused on something else than strengthening the industry and S&T advancement of the country," said Mr. Jehanzeb Khan, former CEO of Akzo Nobel Pakistan Limited.

(ii) Firms

Firms are at the core of any NIS and directly impact its performance. The firms in the Pakistani NIS have not deepened their technological abilities over the years and their response to technological changes has been passive and extremely slow. The last Enterprise Survey, conducted at the firm level, by the World Bank in 2013 shown that only 28.9 % of the firms surveyed introduced new or significantly improved products or services over the three years preceding 2013. Similarly, just 16.2 % firms spent on formal R&D activities, either in house or contracted with other companies.[12] It is a dismal situation as innovation on the ground takes place within firms which ultimately propels the growth of any country. A large number of the interviewees (about 44) shared the same view for poor performance of the Pakistani firms from the perspective of S&T and R&D.

The analysis of the qualitative data also reveals that the culture of innovation and R&D is generally missing among all kinds of firms – small,

big, local and Multi-National Corporations (MNCs) – in Pakistan. In fact, there is a serious deficit of R&D in the country, and a large portion of the firms are technologically backward. Ms. Sunny, General Manager of the Chinese electronics company TCL said in her interview, "We are not coming to Pakistan for R&D as we do not expect it to be very high here. We just want to sell our goods." Similarly, Zong Pakistan, a subsidiary of China Mobile and its first international establishment has been operating in Pakistan since 2009 but does not have any R&D centers here.

It is not only the MNCs that do negligible or no R&D in Pakistan, the local firms are also not too much interested in R&D as many of these are focused on short-term gains and several do not have the capability and resources to conduct R&D. "Local industry believes in low-end imitation and not innovation," remarked Mr. Adnan Arshad, Director of Munawar Pharmaceuticals in his interview. Most of the businessmen in Pakistan do not make research related investments due to the high risks and exorbitant costs involved. A major portion of the profits they earn are invested in real estate which has been a flourishing business in Pakistan for many decades. Mr. Nauman Kabir a politician and former minister of the government of the province of Punjab was very vocal when he explained how Pakistani businessmen invest in commercial lands for returns and not industries. He regarded this as unfortunate and detrimental to the economic growth of the country.

The appetite for research and technological development is clearly missing in the Pakistani industry. "We are myopic. R&D is a slow process. If we start today, the results may come in 10-20 years. We are not that patient," were the views expressed by Dr. Shahab Khokhar, Director of Remington Pharmaceuticals in his interview. Similarly, Mr. Nadeem Iqbal Sheikh, CEO of Nadeem Surgical averred that there was total absence of R&D in the surgical goods industry which has traditionally remained internationally competitive sector of Pakistan. Some local firms in light engineering are doing reverse engineering and producing cheap versions of imported machinery such as China did for some time after opening up.

However, the number of these firms is quite low. Even MNCs established in Pakistan operate like local firms. This is the main reason that whatever research they do is not appreciated too much globally. For example, Glaxo Smith Kline Pakistan – a leading international pharmaceutical is treated quite differently from Glaxo Smith Kline United Kingdom by the international community for any R&D outputs. The majority of the domestic firms in Pakistan are struggling with enhancing and improving their engineering and design capabilities. Small and medium enterprises (SMEs) are preoccupied with building basic operational capabilities and extremely slow upgradation of basic and standard technology.

The environment of Pakistan is also not conducive for entrepreneurship which is extremely important for technological advancement of any country. Dr. Junaid Qadir of Information Technology University stated in his interview, "The overall risk-taking atmosphere is lacking. We need to develop a thinking in our young people that they should not become job seekers rather they should be job creators." In comparison to countries like Nigeria and India which are at a more or less similar level of economic development, Pakistan has a much smaller number of technology hubs and labs. These hubs and labs are considered important for spurring innovation, providing the infrastructure support and facilities for creativity.

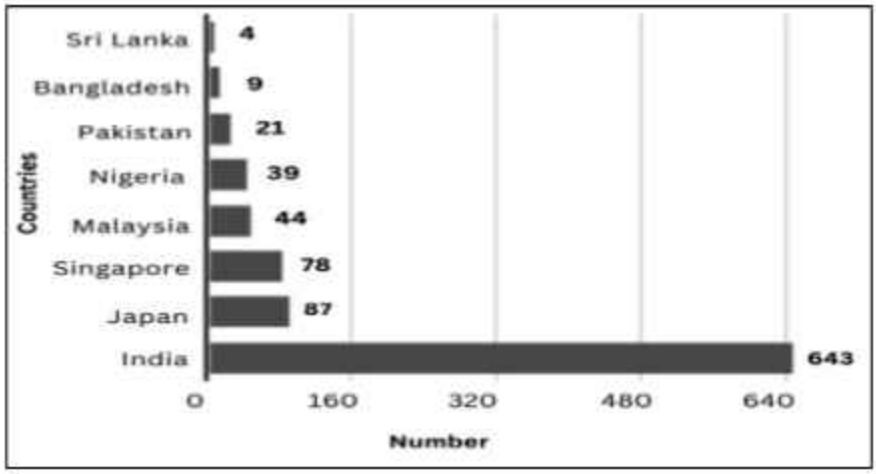
Figure 12 shows for comparative purpose the number of technology hubs, accelerators and funds in Pakistan and some other countries. Pakistan is clearly a laggard and poor performer in this area of S&T.[13]

Compared to India, Japan, Singapore and Malaysia which have 640, 87, 78 and 44 tech. hubs etc., Pakistan has only 21.

Entrepreneurs are generally dissatisfied with the tools and various services provided by the support organizations in dealing with regulatory or legal processes.[14] Startups face setbacks early on due to lack of proper guidance on important issues such as business registration and tax compliance and subsequent costs incurred for the remedial measures, if

any. Incubators in Pakistan are also not quality conscious with their entire focus on the number of startups they graduate.

Figure 12: Tech Hubs, Accelerators and Funds in Pakistan and other Countries (2016)



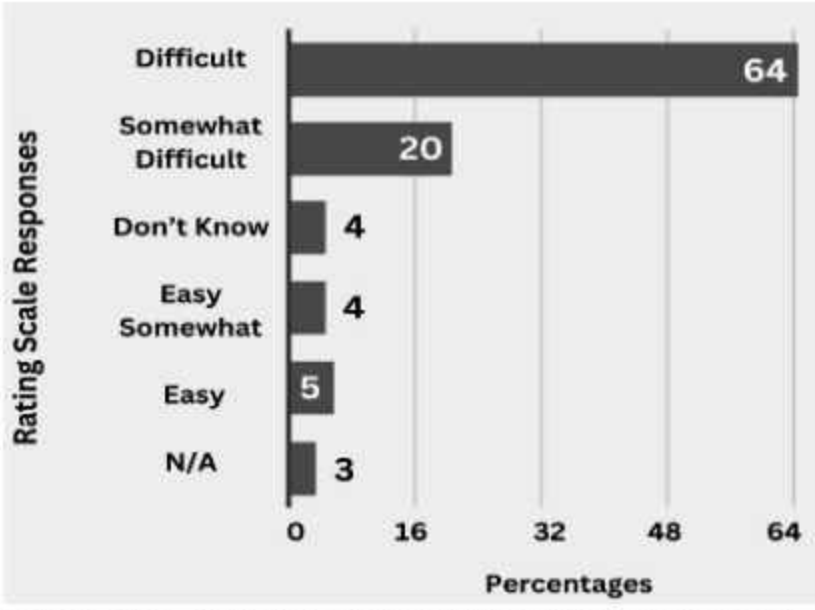
Source: World Bank. (2019e, November 2). Pakistan startup ecosystem report

There are National Incubation Centers (NIC) across major cities of Pakistan. However, they are generally pushed to graduate a minimum number of startups each year usually between 30 and 40. Moreover, the model on which these NICs work also seems to be flawed. The head of a company working on enhancing Pakistan's STI capabilities, on the condition of anonymity revealed: "These [NICs] will fail. They have salaried managers taking a million Pakistani rupees on average per month. They get paid anyway irrespective of success or failure of their respective incubates. Paid incubator managers cannot ensure success of incubates. This model cannot work." The interest of the incubates has to be in fact aligned with the managers of the NICs. Similarly, the mentorship services offered by the support organizations and the quality of mentor match-making by these organizations are generally rated below average by various stakeholders in the startup ecosystem of Pakistan.[15] The financial support for the intermediaries/organizations in the entrepreneurial ecosystem of Pakistan is also scarce. Most of the intermediaries sustain their operations through grants and do not have defined revenue streams.

The dearth of resources for the intermediaries and dependence on grants can become a huge challenge for their long-term sustainability especially when grant and donor funding runs out.

There is yawning early-stage capital gap for startups in Pakistan especially at the pre-seed and seed stages level of funding. There is also a big gap in follow-on financing for startups in view of lack of easy access to loans. The entrepreneurs' rating of investment raising process in Pakistan is seen and perceived as difficult by a large majority (84%) as shown in Figure 13.[16]

Figure 13: Entrepreneur's Rating of Investment Raising Process in Pakistan



Source: World Bank. (2019e, November 2). Pakistan startup ecosystem report

To sum up, the overall state of the industry including the startup ecosystem in Pakistan is very fragile. The only period to stimulate S&T and the industries in Pakistan was during the decade of 1960s. Mr. Habib Ullah, Senior Joint Secretary of the Ministry of Science and Technology (MOST) in his interview said, "This all started in the good old days by Mr. Saleem-

uz- Zaman Siddiqui who was an internationally recognized scientist of Pakistan. He established Pakistan Council of Scientific and Industrial Research (PCSIR) along with several laboratories. So, Pakistan took off in 1960s. Saleem laid the foundation of S&T in that period. Pakistan was going well in that era. Many developments took place during that period such as Agriculture University, Ayub Institute of Technology, Tarnab Farm Institutions." Mr. Shahid Javed Burki, former Finance Minister of Pakistan and Vice President of the World Bank (currently chairman of the Shahid Javed Burki Institute of Public Policy at Netsol) remarked in his interview, "Pakistan's culture has changed a lot. I have worked here from 1960 to 1966 and then I did not work here and remained abroad for my official assignments. At that point in time there was a lot of enterprising culture in Pakistan and thanks to General Ayub Khan for that. Now we are more interested in personal benefit rather than country's benefit or enterprises' benefit. The culture has changed a lot."

Later, Mr. Zulfiqar Ali Bhutto as the Prime Minister of Pakistan, embarked upon the nationalization policy which inflicted a severe blow to S&T advancement and industrialization in the country. Pakistan has never revived after that from the perspective of civilian R&D and S&T advancement of its industrial sector. Bhutto on the other hand is credited with improving Pakistan's defense related R&D with the strategic help of China. He is also regarded as the architect of Pakistan's nuclear program which was eventually made successful with Chinese collaboration.

(iii) Knowledge Infrastructure

The knowledge infrastructure especially the universities engaged in teaching science, technology and engineering are vital actors in the NIS of any country. As for Pakistan, there was a general consensus among the interviewees that the research capacities and capabilities of the knowledge

infrastructure in Pakistan are very weak. The universities and institutions of higher learning do not place any priority on the research endeavor – pure or applied. Universities are mostly engaged in financially more lucrative teaching streams as they are earning revenues from their taught programs, especially for the undergraduates. The burden of teaching and administration on the faculty is thus high and leaves no time for them to indulge in advanced or cutting-edge research. Dr. Sajjad Mubin of the University of Engineering and Technology, Lahore in his interview averred, "I as a professor and my colleague in transportation department have been engaged in administrative and teaching duties and spend about 10 hours per day in administrative work and other teaching related responsibilities. This hectic routine leaves almost no time for us to carry out any research projects." Also, there are meagre funds for the faculty to conduct research. Public universities in Pakistan are especially hard pressed for financial and other resources. "Our institutions [private and public] do not have research-oriented environments," stated Mr. Abdul Rasheed, Director of Industries Department of Sindh in his interview. Dr. Sarosh Hashmat Lodi, Vice Chancellor of NED University – one of the biggest STEM institutions in Pakistan – observed: "I also see that professors in many universities of Pakistan are actually teaching more and researching less. Teaching is a small part of what a university professor should do."

The Higher Education Commission (HEC) was established as a statutory body by the Government of Pakistan in 2002 to, inter alia, formulate higher education policy, ensure quality education and upgrade the performance of the universities and degree awarding institutes (DAIs). The main focus of HEC is on advancement of scholarship, higher learning, research and development. All universities and DAIs in the public and private industries are required and encouraged to have fully functional R&D Divisions/Units for undertaking research initiatives. For this purpose, HEC has encouraged establishment of Offices of Research, Innovation and Commercialization (ORIC) at the tertiary institutes of Pakistan to stimulate the development of much-needed research culture for

knowledge and technology generation, expansion, and commercialization. This would also facilitate connecting university research and commercialization with the private sector in Pakistan and beyond. HEC has also launched various initiatives to promote research within the university system and develop industry-academia linkage. Some of the notable initiatives include:

- The National Research Program for Universities (NRPU) to support scientific research in areas essential to the requirements of the nation;
- The Start-Up Research Grant Program (SRGP) to finance and help newly recruited PhD professors to set up fundamental research infrastructure;
- University-Industry Technology Support Program (UITSP) to assist the local industry in overcoming obstacles to its ability to compete and sell its goods on a worldwide scale;
- Outstanding Research Awards (ORA) to recognize outstanding work in research;
- Access to Scientific Instrumentation Program (ASIP) to offer researchers equipment and other services on a cost-plus basis;
- Business Incubation Centers (BICs) to encourage innovation and entrepreneurship and technology transfer to lead to startups and business incubator centers;
- The Pakistan Program for Collaborative Research (PPCR) to enable academics from developed nations to visit Pakistan or allow Pakistan professors to travel abroad for collaborative research;
- The Technology Development Fund (TDF) with the assistance of ORICs to strengthen academia & industry linkages; and
- Ignite funds for startups and innovative projects in the fields of health, education, energy, agriculture, telecom etc.[17]

The focus of these interventions is on solving current industrial, economic, or technological problems which will ultimately lead to value creation, innovation, import-substitution and indigenization and eventual positive socio-economic impact. Climate change and its impact on e.g., agriculture, food security, urban development, pollution, disaster management, biodiversity conservation etc., is an important area covered by these initiatives. HEC in collaboration with the Intellectual Property Organization (IPO) Pakistan and MOST, has also established Technology and Innovation Support Centres (TISCs) under the auspices of the World Intellectual Property Organization (WIPO) in 39 Higher Education Institutes (HEIs).[18]

These efforts, though laudable, have failed to yield the intended results especially collective, harmonized and tangible outcomes in institutionalizing and internalizing the creative, innovative and technology generation culture within the troika of universities, government and private sector. The overall capacity within the knowledge and technology infrastructure has not been augmented for the accelerated orientation and stimulation of technology development, dissemination and adoption in the country. The weak linkage and connection among the government, university system and private sector continues to impede the development of a robust innovation and technology system. There is hardly any ORIC across Pakistan which is performing well. The process which established the ORICs at the universities was also flawed. "All ORIC documents are poorly designed. No Terms of Reference were sent to us and no well-defined criteria were communicated to evaluate the documents when ORICs were established by the HEC," remarked Dr. Zubair Iqbal Ghauri, CEO of the Lahore Knowledge Park Company (LKPC). "It should be the duty of ORIC to facilitate the patenting process and commercialization process for inventions but unfortunately it is doing nothing," remarked Dr. Sajjad Mubin of the University of Engineering and Technology, Lahore.

The functioning of the HEC also requires significant improvement. For example, it treats a top-tier university of Pakistan like the Lahore University of Management Sciences (LUMS) in the same manner as a newly established university when dealing with research applications. "So even universities like LUMS which are teasing the frontiers of technology and knowledge are discouraged by downright frustrating paperwork requirement". It has also become very confusing as the provinces have their own HECs distinct from the Federal HEC. Universities are not clear from where to get directions. "You don't know whom to report and from whom to get funding. Look at the formalities that academics in Pakistan are subjected to when they want to go for conferences. It is demeaning," said Dr. Izza Aftab of the Information Technology University at Lahore in her interview.

University system: Majority of the graduates being churned out from the universities of Pakistan lack the required level of knowledge and expertise and creative and analytical ability. "I have interviewed a large number of people for hiring purpose. The stuff being created by us in our universities is very disheartening. A large portion of the applicants' lack innovative thinking," said Mr. Abdur Razzaq, Chief Operating Officer (COO) of the LKPC. The quality of the Pakistani universities and their graduates can be well gauged from the QS World University Rankings (2023). There are only three universities from Pakistan in the top 500 universities of the world i.e., National University of Sciences and Technology (334), Quaid-e-Azam University (378) and Pakistan Institute of Engineering and Applied Sciences (398). The situation worsens if we consider the Times Higher Education rankings for 2021 - no university of Pakistan figures among the top 500 universities of the world.

During field work in the industrial city of Sialkot, Mr. Ammar Faisal Al Assad, Manager finance, Talon Sports echoed the same concern as Mr. Abdur Razzaq, "We have many vocational and technical institutes, but the output and outcome is not at all commendable. Similarly, graduate

engineers have not proven their worth in Sialkot's industry." The head of a company working on enhancing Pakistan's STI capabilities, on the condition of anonymity said, "We do not teach how to think creatively to our students in our universities."

Thus, the majority of the universities of Pakistan are turning into teaching institutions due to the neglect of research and analytical studies. The collaborative research effort by and large does not exist as the universities fail to share knowledge or interact and are working in silos to the exclusion of others. They lack motivated intellectual workforce which can dedicate time for producing cutting-edge and path breaking research. Over the last decade or so the HECs– federal and provincial – have been putting pressure on the faculty to produce research which led to the focus on quantity without any attention to quality and relevance. In fact, the relevancy of the research to the industry is very low. Dr. Tahir Izhar of the UET, Lahore, said in his interview, "Our professors don't write any books and they have handwritten notes through which they teach, and these eventually disappear with the passage of time. Why don't we establish university presses like Cambridge, Oxford, MIT, Harvard, etc. through which our professors may publish quality books with convenience?" Similarly, Ms. Maryam Mohiuddin, Director of the Social Innovation Lab said, "Research universities and institutions are not doing enough to change their internal policies and encourage more folks to do deeper R&D and then commercialize it." In general, there is little understanding and realization among the stakeholders that the universities must perform with equal commitment all the mandated functions viz., teaching, research, human resource development, providing workforce for the industry and developing the nation for the future. It needs to be understood that universities remain relevant to a society only when they focus on all the afore mentioned functions".

Another worrisome aspect about the universities is the politicization of the process for establishing new universities. HEC is giving charters to degree awarding universities without any feasibility

study. An interviewee on the condition of anonymity explained, "There are political pressures for awarding charters to the universities. A well-known politician in the previous political regime pressurized the HEC to establish and grant charter to an engineering university in his district (Narowal). Gujranwala which is an industrial city near Narowal, has no engineering university, but Narowal got one due to the influence of that politician. The question is why an engineering university in Narowal and not first in Gujranwala which has many industries." Given this situation, it will be extremely difficult to think and conceive of any industry-university collaboration for R&D projects and S&T advancement.

Technical and Vocational Training: The Federal and Provincial levels skills development institutions in Pakistan such as the National Vocational and Technical Training Commission (NAVTTC) and Technical Education and Vocational Training Authority (TEVTA), provide only low- end skills e.g., plumbing, carpentry, masonry, etc. The training curricula are also outdated which are mostly supply driven and not responsive to the industry or demand of the labor market. The National Skills Strategy 2009-2013 envisaged a paradigm shift from curricula-based education to competency-based training to provide relevant skills for industrial and economic development, improvement of access, equity and employability and assurance of quality through an integrated approach. National Vocational & Technical Training Commission (NAVTTC) was involved in training 25,000 young graduates in more than 195 market-oriented courses under the Prime Minister's Youth Skill Development Program to help fresh graduates acquire necessary skills for a better job hunt as well as minimize the gap to meet employers demand.[19] The National Training Bureau (NTB), on the same lines, attempted to impart market- oriented skills to a target of 34,000 trainees through public-private partnership. National Internship Program initiated by the Government of Pakistan also envisaged skills and human capital enhancement in Pakistan.[20] However, the desired results could not be achieved because of lack of strategic vision and coherent implementation framework. A skills deficit mapping exercise both for the domestic market and the regional and global markets which is prerequisite for designing the curricula and identifying technical training priorities has not been undertaken as yet. Interestingly, one of the authors has also worked for

NAVTTC. He had to eventually leave the organization voluntarily due to its ineffectiveness. There is, thus, no discernable effort on the part of these government operated skills development institutions to create qualified and properly skilled manpower conducive for innovation and technological development of the country. The government has also not come up with the appropriate set of policy measures and incentive structure to stimulate private firms' investments in skill development and training which is a key tool for sustainable growth. According to a World Bank report, only 6.7% firms were offering formal training for skills development[21] which eloquently speaks of the prevailing weak and fragile skills and human capital development in the country.

It is to be noted that globalization and economic liberalization have brought to the fore the significance of entrepreneurship, skills and human capital development as absolute imperative factors for technological advancement and socio-economic growth for any nation. However, the current socio-economic and institutional landscape presents a gloomy picture which stifles innovation and adversely impacts country's endeavor to catch-up and gain a sustainable level of economic development. It needs to be recognized that skilled human resource is a prerequisite to nurture innovation and technological development and enable the country to proactively adjust, adopt and respond to the enormity of present-day development challenges. It also needs to be realized that Pakistan is one of the most populated countries with an estimated population of more than 240 million in 2023. Around 64% of total population is less than 30 years of age providing a great opportunity for skills and expertise development needed for a knowledge and entrepreneurial economy to harness the potential and opportunities of local and global markets.

23. Linkages between Different Actors of Pakistan's Innovation System

For understanding the performance of the NIS of any country, it is important to understand both the extent to which its components perform their roles and their linkages. Organization for Economic Cooperation and Development (OECD) has developed a framework for the NIS to map the main actors and their role in innovation processes viz. firms, public and

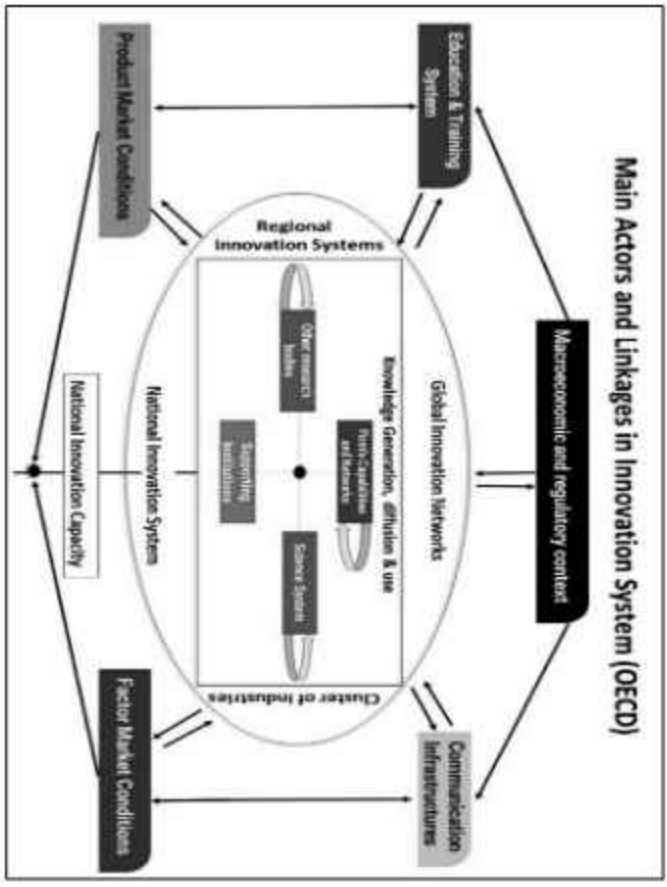
private research organizations, and government and other public institutions (OECD).[22] Figure 14 depicts the pictorial visualization of the NIS framework.

As is evident from Figure 14, the performance of the actors of the NIS and the linkages among them eventually affect the performance of a country (growth, job creation, competitiveness) through its national innovation capacity. For generation, diffusion and adoption of knowledge, innovation and technology, there has to be a connection and capability among the industry, research and academia especially the science system supported by a conducive policy and institutional environment. The upstream macro- economic and regulatory frameworks need to provide stimulus not only to technology and knowledge generation, diffusion and its assimilation locally but also incentivize the local IS to tap into and benefit from global and regional innovation networks, skills development and training systems related to S&T and communication infrastructure.

As regards Pakistani NIS, the linkages between the major actors are characterized by fragmentation, isolation and distrust. Connectivity and linkage are sine qua non to muster creative synergy for technological advancement and innovation.

The prevalent culture of industry and business and public sector in Pakistan, however, stifles attempts if any to achieve this creative synergy through much-needed linkages and connectivity. Same is the case regarding the industrial value chain. The linkages between the producers, the actors and entities along the value chain and the users in Pakistan are also weak. Research evidence shows that strong producer-user linkages are the common basis for innovation.[23] Cooperation between the firms in the same and related industries is also missing. None of the interviewees in various industrial sectors could share or adduce any substantive examples of inter-firm cooperation for innovation in their specific industries. There was indeed an absence of understanding among the interviewees about the importance of cooperative consortiums among firms for innovation.

Figure 14: Main Actors and Linkages in the Innovation System



Source: Organization for Economic Cooperation and Development (1999).

The links between the Pakistani knowledge infrastructure and industry are also episodic and fragile with a dearth of organizational commitment to foster and forge these links. As discussed earlier, Pakistan's universities have poor research infrastructure and capability and most of their research does not have any industrial relevance. There are some sporadic linkages which are based on personal connections between individual researchers and industry. Firms usually involve universities for short-term training, ad hoc use of consulting and research activities rather than long-term extensive relationship. "I have yet to see a concrete example of industry academia linkage," stated Ms. Maryam Mohiuddin, Director, Social Innovation Lab. Ms. Yasmin Masood, Secretary MOST said, "Linkages between universities and business in Pakistan's NIS are poor due

to a number of reasons such as: non-realization of the importance of linkages between various stakeholders, communication gap amongst universities and industry and lack of trust between various stakeholders." Dr. Sarosh Hashmat Lodi, Vice Chancellor of NED University remarked, "Over the years, I have seen the industry losing confidence on university for getting research done. Government also has no understanding of the importance of university-industry linkages."

Industry and academic institutions in Pakistan generally operate in silos. Mr. Ye Yi, CEO of Dongfang Electric in Pakistan said, "Nobody has ever approached my company since it started its operations in 1988. So many universities are there in Pakistan, but no one has ever approached me for any collaboration or joint projects." Same views were echoed by Ms. Sunny, General Manager of TCL in Pakistan. Thousands of graduates from STEM institutions do not get absorbed by the industry due to irrelevant skills and knowledge being given to them. Dr. Tahir Izhar of UET, Lahore, remarked in his interview, "In the Pakistani market there are 50,000 plus electrical engineers who are jobless or doing irrelevant jobs. The main reason for this is the irrelevant knowledge (not in demand by the local industry) given by us at the university."

The collaboration between public research technology organizations (RTO), many of which are operated by MOST, and the industry are negligible or absent. Mr. Siddique-ur-Rehman Rana, Chief Executive of Technology Exchange and Coordination remarked: "The institutions and organizations working under MOST have no link with the industry". None of the interviewees from the industry shared any experience of utilizing RTOs as a source of information for any of their STI activities as these are mostly ill-equipped and have not played a significant role in deepening technological capabilities of the Pakistani industry.

Against this backdrop, the next part VII provides an objective analysis of Pakistan's technology and innovation landscape with some comparable selected countries to identify the extent of deficit, if any, to be

able to prescribe the corrective measures for catch-up and lay down the basis for setting us a well-functioning and sustainable NITS.

Notes

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[15] Ibid.
[16] Ibid.
[17] R&D programs and support initiatives policy handbook 2017: HEC
[18] https://www.nation.com.pk/01-Nov-2022/global-innovation-index-2022
[19] Shabbir, 2009; Shariff et al., 2016: 2016a
[20] (Abidin et al., 2015; Abidin & Haseeb, 2015, 2018; Haseeb, 2018; Haseeb et al., 2014).
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Part VII: Comparative Analysis: Technology and Innovation Landscape

24. The Country Capacity

The economic development and growth of a country in the rapidly changing and globalized world depend upon its capacity to closely integrate into and become part of the fast-evolving regional and global production and knowledge networks. This, a priori, entails strengthening and deepening the science, technology (S&T) and innovation infrastructure and capability to maximize the benefits and opportunities unfolded by these changes, develop and upgrade efficient value chains to become part of the regional and global production networks and create entrepreneurial-knowledge economies. Some of the developing and emerging economies have managed successfully to achieve rapid industrial progress and economic growth by expanding their technological frontiers and developing new institutional and innovation capabilities to sustain their international competitiveness. Constantly improving the conducive environment for technological development, creation of knowledge and know- how, institutional coordination, a synergy between education, research and industry and robust legal and financial frameworks constituted an integral part of their development strategy.

There was a conscious realization that technological innovation and advancement is more likely to succeed if the broader environment including the values, norms and legal frameworks enveloping the private sector industry and research and academic institutions is well articulated and inter-connected into a coherent innovation and technology system. In order to ensure its operationalization, appropriate and enhanced budgetary allocation for research and development, introduction of scientific and interactive learning and education system which stimulated creative enquiry and research, and institution of a comprehensive intellectual property regime were absolute imperatives. The enabling frameworks in turn, among other things, secured and protected the patents as valuable

assets (product, design or process) and recognized the exclusive right of the inventor for his or her innovation and invention. A coordinated and dynamic interactive relationship between the formal institutions i.e., industry, research institutes and universities for knowledge-technology creation and use was also facilitated. The result was a radical improvement in the functional performance of the overall innovation system and the accelerated growth and development of the country. The following section gives a comparative appraisal of some of the specific indicators and elements of selected developing and emerging economies which are indicative of the extent of their commitment to catalyze and shape their respective innovation systems.

a) Gross Domestic Expenditure on R&D (GERD):

Gross domestic expenditure on R&D (GERD) as a percentage of GDP is one important input indicator of innovation in a country. Table 4 shows Pakistan's GERD from 2010 to 2021 which as is evident has come down from 0.389% of GDP in 2010 to only 0.241% of GDP in 2019. The average GERD of Pakistan from 1990 to 2009 (data not shown here) was 0.267% of its GDP. For the period from 2010 to 2021, Pakistan's average GERD came to 0.247.8% reaching a very low level of 0.16% in 2021.

Table 4: GERD (% of GDP) in Pakistan (2010-2021)

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
GERD	0.389%	0.329%	0.311%	0.293%	0.270%	0.256%	0.241%	0.236%	0.239%	0.241%	NA	0.16%

Source: World Bank (2024), United Nations Educational, Scientific and Cultural Organization(2020a).

This low GERD of Pakistan compares unfavorably with some other low-middle income countries of the world as shown in Table 5

Table 5: GERD (% of GDP) of Pakistan Compared with other Low Middle-Income Countries

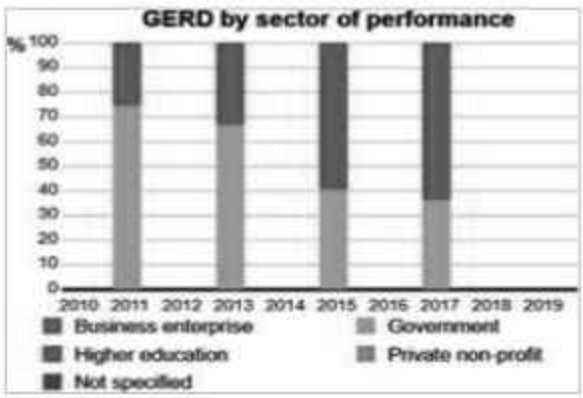
Country	Pakistan	India	Vietnam	Egypt, Arab Rep.	Philippines
R&D Expenditure (2021)	0.16	0.66	0.42	0.80	0.32

Source: World Bank (2024)

The neglect of GERD by the successive governments speaks volumes of the level of their commitment to advance technology and innovation. A deeper analysis by breaking down the GERD into various components and then comparing it with some other low middle-income countries, however, reveals a more alarming situation of the Pakistani NIS. As shown in Figure 15, only the government and higher education sector of Pakistan are contributing towards the GERD. Business enterprises are doing almost no R&D which means that the private firms are not innovating and delivering superior products and services which are required for any economy to become competitive in the fiercely contested global arena. Contrary to Pakistan's situation, the business sectors of India, Vietnam and the Philippines are contributing much more towards the GERD of their countries as shown in Figure 15 (latest data available). Even Egypt's business sector (with very low overall contribution towards GERD) is doing better than the Pakistani enterprises.

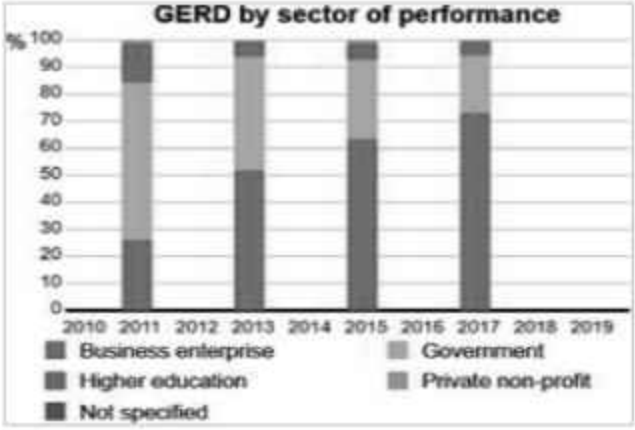
Figure 15: GERD by Sector of Performance

(a) Pakistan

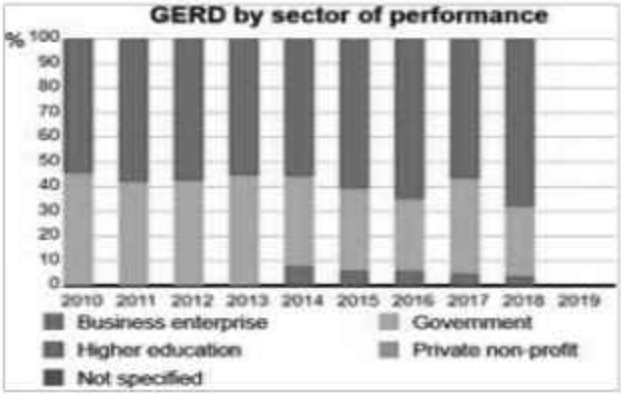


(b) India

(c) Vietnam

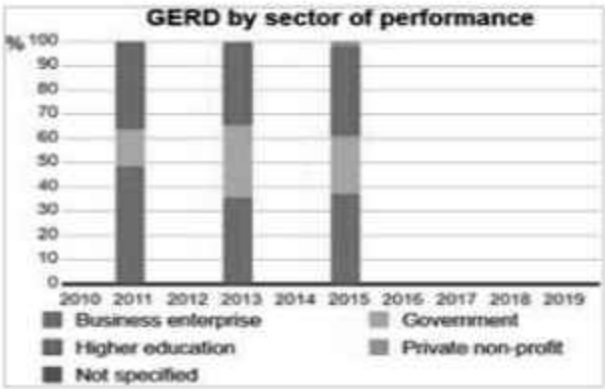


c) Egypt



Source: United Nations Educational, Scientific and Cultural Organization (2020b).

(e) Philippines



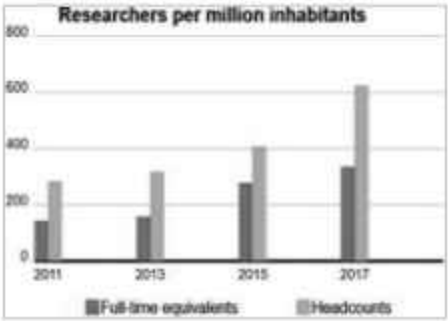
Source: United Nations Educational, Scientific and Cultural Organization (2020b).

b) Researchers per Million Inhabitants:

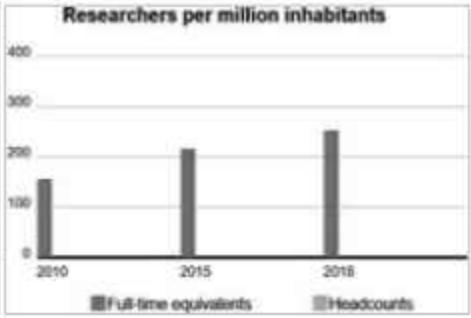
Another important input indicator of innovation is the number of researchers per million inhabitants in a country.[1] Figure 16 shows the researchers per million inhabitants (Full Time Equivalent and headcount) in Pakistan in comparison to some selected low-middle income countries. The number of Full Time Equivalent (FTE) researchers in Pakistan is better than in India and Philippines but worse than Vietnam and Egypt. The situation remains the same even when compared with the countries on the basis of headcount. There is a big room for improvement on this input indicator if Pakistan wants to enhance its innovative capacity and global competitiveness.

Figure 16: Researchers per Million Inhabitants

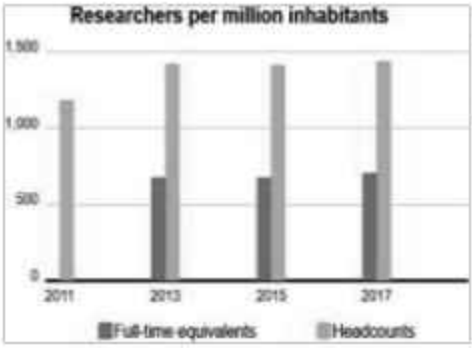
(a) Pakistan



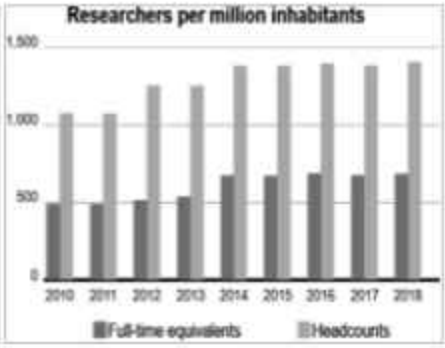
(b) India



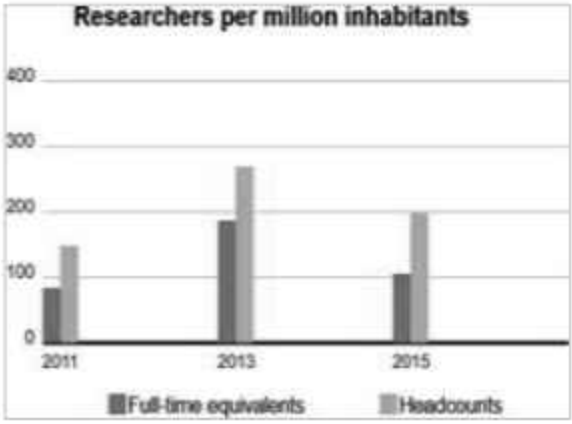
(c) Vietnam



(d) Egypt



(d) Philippines



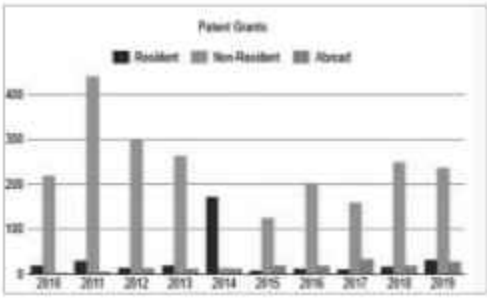
Source: United Nations Educational, Scientific and Cultural Organization (2020c).

c) Data on Patents:

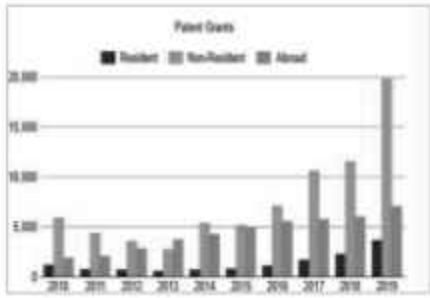
Along with GERD and number of researchers per million inhabitants, data on patents are regarded as an important performance indicator of innovation in any economy. Patents are in fact output indicators of innovation and R&D activities. Figure 17 (based on latest data available) clearly shows Pakistan's dismal performance in comparison to other developing and low-middle income countries. India, Vietnam, Egypt and Philippines are way ahead of Pakistan in terms of patents granted. Statistical data on the various input and output indicators validates the main findings of the qualitative section of this report – Pakistan's NIS is very fragile.

Figure 17: Patent Grants

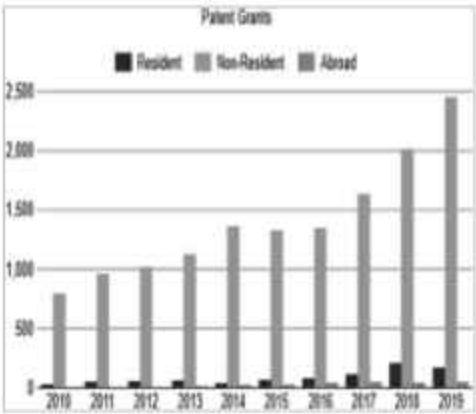
(a) Pakistan



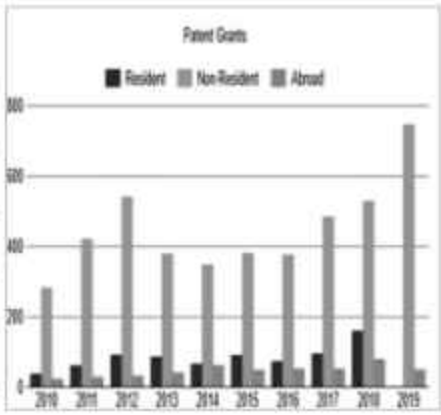
(b) India



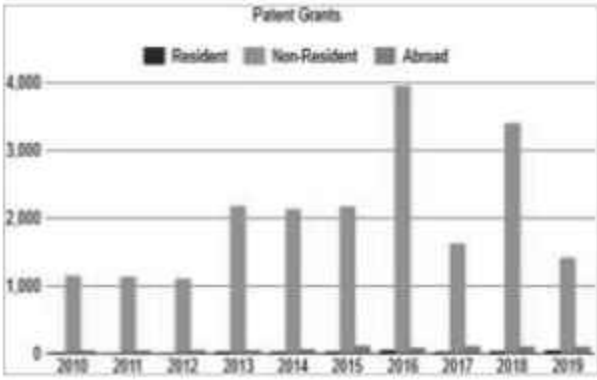
(c) Vietnam



(d) Egypt



(e) Philippines



Notes

[1] Number of employees are counted in two basic ways (FTE and headcount). Headcount counts each individual person as one employee whether he/she is working part time or full time. FTE tells us the number of employees who are working full time

Part VIII: Major Issues and Challenges

The choice of pursuing a knowledge economy and the associated prerequisite of establishing a robust and efficiently operational national innovation and technology system requires a strong resolve and commitment at the highest political level to be able to transform the structure of the economy and existing knowledge infrastructure. It is not only the articulation of a shared vision to implement a technology-innovation driven knowledge economy paradigm but more importantly, it is managing the intended change through a composite implementation framework. It involves strengthening of human skill set and assets, adequate allocation of budgetary resources, restructuring of the institutions, process and procedures engineering, systems upgradation and last but not the least permeation of innovation culture across all levels of public, private and academic entities. Impatient leadership devoid of critical thinking, lack of ownership, exclusion of the major stakeholders and inherent status quo cum obsolescence are the prime impediments which characterize the innovation landscape in Pakistan. The rapidity of technological change, increasingly competitive global order, need for a more skilled, flexible and diverse workforce and above all the rising expectations and standards of client-citizen satisfaction are some other notable challenges to deal with for a smooth transition to a knowledge based economy. Market failures for transferring scientific knowledge to practical use and developing new technological products are common which at times entail huge costs and risks and may show results with substantial lag. Much also depends upon the amalgam of choices to promote innovation and technology-based approach e.g., incremental innovation, breakthrough innovation, technology or altogether disruptive innovation etc. More specifically, some of the major challenges and issues for the innovation system, including the ones identified by the interviewees are as follows:

25. Government - Policy and Institutional Framework

Policy Framework: The overall environment in Pakistan to create a technology savvy and receptive culture or appetite which is extremely important for the technological advancement of the country is conspicuously lacking. The macro-S&T policy framework is fragile and grossly inadequate both in terms of transforming and obligating the state apparatus including the major sectors to espouse technology and innovation development (HR, tools, systems, products and services) and incentivizing academia – university system and private sector to develop linkages for technology and innovation stimulated productivity gains and competitiveness. This is self-evident from the dearth of effort on the part of the government – which has formulated only three S&T policies i.e., 1984, 2012 and 2021 since independence and those too characterized by fragmentation, incoherence and financial deficit. A visible disconnect within the government machinery and higher learning-university system and the private sector is also vividly discernable. These policy frameworks do recognize the need for human capital management and development, transformation of knowledge into product and strengthening the innovation eco-system, tapping into new and emerging frontiers of technology etc., but woefully lacked implementation, monitoring and follow-up mechanisms. They also failed to attract foreign direct investment (FDI) or foreign investors to help the country advance technologically and catch up especially in various sectors as positively experienced in many other countries of Asia (China, South Korea, Singapore). The big Multinational Corporations (MNCs) and corporate sector have been operating in Pakistan in important sectors such as telecom, electronics, automobiles, pharmaceuticals, etc., for many years but have not forged much-needed strong links with the local firms or even linkages between them and their subsidiaries to assist Pakistan in acquiring, improvising or adopting the related technology and innovation models.

Institutional Support: As regards institutional support, the Ministry

(MOST) is the least priority of the government. The 14 institutions working under the MOST, most of which are autonomous, seem to work in their own silos without synergizing and coordinating their technology and innovation related mandates. There is also a conspicuous absence of a strong ministerial lead on improving the competitiveness of Pakistan. The innovation agenda of government in Pakistan indeed presents a disconcerted and sporadic landscape aggravated by a mismatch between the expertise mix and the job role. The World Bank in a study also observed that the entrepreneurs expressed their dissatisfaction with the tools and various services provided by the support organizations in dealing with regulatory or legal processes.[1]

Budget allocation: The budget allocated to and the expenditure incurred on R&D by the government and private sector to S&T are of crucial importance. They include both capital and current expenditures in the four main sectors: business enterprise, government, higher education and private non-profit and cover basic research, applied research, knowledge and know-how generation and piloting development intervention to validate and upscale. Pakistan's record on this account is dismally poor as is evident from the meagre allocation of 0.16 % of GDP for the year 2019-2020[2] (latest available figures). During 1996 to 2020, it averaged around 0.26 % with a minimum of 0.11 % in 1998 and a maximum of 0.63 % in 2007. For comparison, the world average in 2019 based on 88 countries was 1.13 %. Israel ranked number 1 with 5.44 % followed by South Korea with an allocation of 4.81 % of the GDP, China at number 12 with 2.4 % and Turkey at 32 with 1.09 % of the GDP during the period 1996-2020. Iran, India and Bangladesh spent 0.9, 0.7 and 0.3 % respectively of their GDP on R&D. Bangladesh plans to increase it gradually to at least 2.5 % of GDP by 2030.[3] Accordingly, the overall infrastructure in Pakistan in terms of technology labs, supportive hubs for innovation and creativity is inadequate. The country has a much smaller number of technology hubs and labs compared to countries like Nigeria, Malaysia and India.

Ease of Doing Business: Ease of Doing Business (EODB) Index is the measure of business friendliness of a country which ranks the countries based on an average of ten sub-indices including:

- starting a business;
- procedures, time, cost, and minimum capital to open a new business;

dealing with construction permits;

- procedures, time, and cost required for business to obtain a permanent electricity connection for a newly constructed warehouse;
- procedures, time, and cost to register commercial real estate; getting credit;
- strength of legal rights index, depth of credit information index; protecting investors;
- indices on the extent of disclosure, the extent of director liability, and ease of shareholder suits;
- paying taxes, number of taxes paid, hours per year spent preparing tax returns, and total tax payable as a share of gross profit, trading across borders;
- documentation, cost, and time necessary to export and import enforcing contracts;
- procedures, time, and cost to enforce a debt contract; resolving insolvency;
- the time, cost, and recovery rate (%) under a bankruptcy proceeding.

A country cannot advance in the domains of S&T unless it creates a comfortable environment for the businesses. Table 6 shows the Ease of Doing Business Index, 2020 (latest data available) ranking of the eight countries of South Asia where Pakistan is geographically located.

As is evident, Pakistan continues to remain a poor destination for a business-friendly environment. The government of Pakistan must do a lot more to improve Pakistan's ranking if it wants the country to industrialize and improve its S&T performance specially to address the weakness in the current regulatory environment and general discontent among businessmen against the taxation regime.

Table 6: Ease of Doing Business Index Rankings 2020

Country	Ranking
India	63
Bhutan	89
Nepal	94
Sri Lanka	99
Pakistan	**108**
Maldives	147
Bangladesh	168
Afghanistan	173

Source: State Bank of Pakistan https://www.sbp.org.pk › Ease › Ease-

Conducive EODB enables the setting up of new and young entrepreneurial firms with a higher propensity to innovate in terms of both product and process innovation. Venture capital is an integral part of EODB so are: better regulatory environment, debtor friendly bankruptcy and insolvency laws, levels of infrastructure and business facilitation. It was regrettable to hear from a Chinese national, during the interview that even the basic things such as one window solutions for establishing firms in the newly rolled out SEZs of CPEC were missing. An investor needs to contact multiple government agencies for starting the business which range from the local land authorities and district administration to the Federal Board of Revenue. The bleak state of affairs of SEZs was even averred by Mr. Ahsan Ali Mangi, Secretary, Investment Department of Sindh when he remarked: "There is no electricity, no gas, nor roads in a part of Port Qasim SEZ. SEZ Act 2012 has been made by the government and it says that there will be no tax on income. But when you look deeply at that Act, you find that you have to pay 1.5% tax on your turnover." These contradictions discourage investors and at the same time are antagonistic to the STI landscape of the country.

Last but not the least, the functioning of Pakistan's state apparatus and bureaucracy is marred by cumbersome procedural delays, red tape and status quo orientation. "Our bureaucratic culture is anti-development and

hindrance in our technological progress" were the remarks in a meeting with a World Bank representative, who regarded the Pakistani bureaucracy as the most regressive bureaucracy anywhere in the world. (Mr. Faisal Fareed, Task Team Lead Consultant of the Punjab Spatial Strategy, The Urban Unit). Mr. Faisal Sherjan, Director of the National Incubation Center at Lahore lamented the government's negative and obstructive role: "extractive politics and rent seeking is creating a lot of problems for businesses, investors and entrepreneurs." As such, transformation of bureaucracy from reactive to proactive and problem-solving dynamic state apparatus is fundamental through capacity building, technical expertise and professional development.

Structure of Economy: There are structural issues with Pakistan's economy and planning system which tend to discourage investment in S&T and somehow support the status quo in terms of perpetuating the technology and innovation averse culture. The inertia commitment and incremental approach to economic management and planning and programming function both at the federal as well as provincial levels seem to be the major determinants of resource allocation based on path dependence. The country needs to change the course and go beyond rhetoric to shift to an entrepreneurial and knowledge economy which, a prior, entails prioritization of S&T to be able to engender and create innovative economic activities. The investment in science will help Pakistan to shift from raw material export to value-added export. The country is the repository of huge mineral reserves comprising 92 identified minerals, out of which 52 are mined commercially with a total annual production capacity of 68.52 MMT. The sector registers on the average growth rate of 2 to 3% per year. Chromite is one of the most important minerals. In 2021, total value of chromite exports was $95 million with China importing a share of more than 85% at a low price of $206 per ton. If the country develops and deploys technology and innovation and establishes high-tech processing plants to add further value to chromite (ferrochrome), it could fetch $1,212 per ton from export to China.[4] The raw material economy can never be competitive nor can achieve high

export targets. Only value-addition through innovative technology can ensure the economic security of Pakistan. Traditional economy and lately the poor economic performance have led to a very high rate of brain drain while investment in new technologies will create new ventures, generate employment opportunities and increase the growth of businesses besides retaining talent in Pakistan.

26. Private Sector: The Missing R&D and Innovation Culture

The overall picture of the industry is disappointing which lacks commitment to invest in technological upgrades as is palpably evident from a very low percentage of new or improved products or services being introduced into the market. If at all, low-end reverse engineering and production of cheap versions of imported machinery appears to be the focus of technology acquisition.

There is no credible evidence to suggest inter-firm cooperation for innovation or training and skills development of their professional as well as technical staff in their specific industries. This is true across various industrial sectors as vehemently pointed out by the interviewees. If at all, firms usually involve universities for short-term training, ad hoc use of consulting and research activities rather than long-term extensive relationships. That too, over the years, is on the decline due to industries' loss of confidence in universities for getting research done. The government also has no understanding of the importance of the government-university-industry linkages as envisaged in the Triple Helix Model. Another major impediment in the private sector R&D investment is the overwhelming propensity among the private industrial sector to invest the profits in real estate which has been decades long booming business in Pakistan.

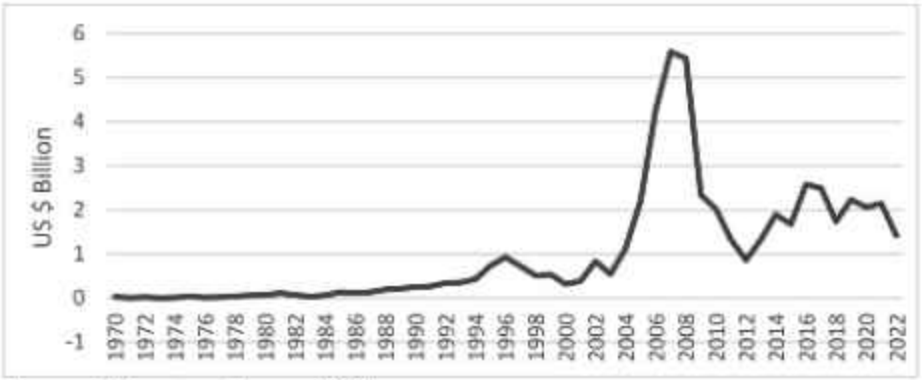
The National Incubation Centers (NICs) established across major cities of Pakistan, as earlier stated do not seem to lead to the development of a sustainable culture or operational practice to generate, improvise or diffuse innovation and technology. The interviewees lamented the

inefficacy of the NICs models which according to them were afflicted with flawed and faulty structure and modus operandi: the salaried managers tended to be more interested in perpetuating their positions than passionately aligned to the incubates' interest and their success. The quality of mentors was generally compromised over preference and convenience of ready accessibility and availability of hand-holders. The funding deficit for early-stage capital for startups in Pakistan and a big gap in follow-on financing for startups is a common feature. Even the MNCs operate like local firms. Their main contention is that the R&D effort conducted in Pakistan is not globally recognized.

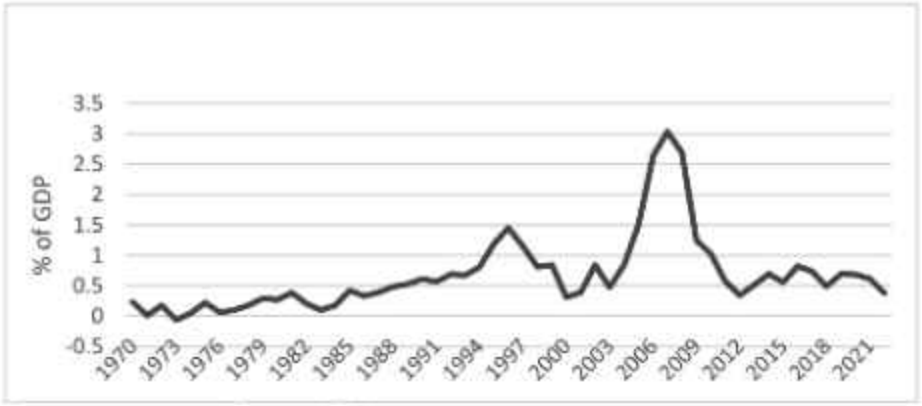
Flow of FDI and Technology from MNCs: FDI refers to the sum of equity capital, reinvestment of earnings, and other capital flows to a country. It is a very important vehicle to develop technology through technology transfer and diffusion and stimulate innovation for increasing productivity and sustainable growth. Pakistan has, however, failed to benefit from the flow of FDIs in various sectors as positively experienced in many other countries of Asia (Bangladesh, China, India, South Korea, Singapore). The historical trend, depicted in Figure 18, shows the flow of foreign direct investment to Pakistan. As is evident, it peaked in 2007 at more than US$ 5 billion constituting almost 3 %of GDP, and declined in 2021 to merely US$2.10 billion with only 0.6 % of GDP.[5]

FDI in Bangladesh during 2021 stood at US$1.72 billion[6] while India attracted the highest ever annual FDI inflow of US$ 83.57 during the FY 2021-22.[7]

Figure 18: Flow of FDI to Pakistan



Source: Macrotrends.com 2024



Source: Macrotrends.com 2024

Pakistan indeed holds enormous potential for attracting FDI. It has a huge domestic market with a population of more than 240 million, a rising middle class and a vibrant demographics. A cheap and abundant workforce, potential for high GDP growth and the measures to attract FDI like guaranteeing equal treatment between foreign and local investors, establishment of SEZs and export processing zones, taxation relief and geo-strategic locational advantage are some of the positive potentials to allure foreign investment. However, obstacles such as low fiscal resources (13% of GDP), a sizeable informal economy (40% of GDP and 60% of employment), exchange rate vulnerability, soaring inflationary risks, fragile manufacturing (20% of GDP) and export base etc., prevent the country to fully harness its FDI potential[8] and benefit from technology

transfer and advancement. Added to these impediments are an onerous business environment, lack of education and healthcare facilities, and above all, domestic and regional security risks.

Big MNCs which are already operating in Pakistan for many years in important sectors such as telecom, electronics, automobiles, pharmaceuticals etc., have also not fostered or encouraged strong links with the local firms or even their own subsidiaries in Pakistan. Mr. Li Qi, Senior Manager Corporate Sales of Zong (a subsidiary of China Mobile in Pakistan) said, "We do all of our R&D in China and there are no R&D centers of China Mobile here in Pakistan." It is hard to think of any transfer of technology especially from designing and engineering perspective in this scenario. Japanese automobile MNCs like Suzuki, Toyota and Honda are also operating in Pakistan since the 1980s and 1990s. They have however, not actively developed sub-contractors or given technical assistance to local suppliers to improve their efficiency through innovation and technological upgrades. The local support industry still remains inefficient and technologically backward. The plants of major automobile companies are simply assemblers and their production, however, is stuck at the bottom rung of technological development. It has taken more than 25 years for the government of Pakistan to promulgate an Automotive Development Policy 2016–2021 that aims to encourage an improvement in the skills, competitiveness, and technology of local production, but many other factors need to be looked into for any advancement, including the macroeconomic situation.

27. The Apathy of the Knowledge Infrastructure: R&D Shy University and Higher Learning System

University and Higher Learning System: The quality of Pakistani universities and their graduates is generally poor as compared to other universities in Asia not to speak of global ranking. Majority of the graduates being produced by the universities of Pakistan is also not good from the angle of creativity. There is a multiplicity of reasons for the universities' sub-optimal performance, including lack of modern

infrastructure (labs, modern teaching aides, tools and systems, libraries etc.), the pedagogy and the methods and practices of teaching, the assessments and grading system, the quality of curricula, the competence and qualifications of the faculty. Only very few professors are engaged in writing books or quality research papers. Reference books are seldom used to enable students to develop insight into the subjects and engage them in creative and critical thinking.

The research capacities and capabilities of the universities and knowledge infrastructure are also very weak as the universities and institutions of higher learning do not place any priority on the research endeavor – pure or applied. There is a pervasive dearth of motivated intellectual workforce dedicated to producing cutting edge and path-breaking research. Most of the professors are entrusted with administrative and more lucrative teaching duties. This hectic routine leaves almost no time for them to carry out any research projects.

As earlier stated, universities are mostly engaged in financially more lucrative teaching streams as they are earning revenues from their taught programs, especially for the undergraduates. Hardly any university has a credible publication program or publishing press like Oxford, MIT, Harvard, etc., to encourage research work and quality publications. The higher learning institutions both private and public, do not provide conducive research-oriented environments. Public universities in Pakistan are especially hard pressed for financial and other resources. From the research collaboration perspective, the universities are not interested to develop linkages and inter and intra disciplinary teams; instead, they have created walls among themselves and work in silos.

The politicization of the process for establishing new universities has further ledto the institutionalized commercialism of higher education with profit motive being the major consideration in the private sector. These universities are being granted charters without any feasibility study. It was repeatedly asserted by many interviewees that politicians pressurize the Higher Education Commission to award charters to private universities

solely on political considerations.

Higher Education Commission (HEC): HECs diffusion at federal and provincial levels and lack of functional coordination is again a major bottleneck in promoting research. There is a constant turf battle between Federal and Provincial HECs which fails to provide coherent leadership and stewardship to the universities in ensuring quality education and conforming to the prescribed research standards. The HEC blindly applies sub- optimal standards without paying heed to and differentiating between the top tier universities and newly established universities. For ORICs established at the tertiary institutes of Pakistan to promote R&D and incentivize innovation and technology, there is no effective monitoring mechanisms or policy guidelines to ensure the functional optimality of these ORICs. The ORIC documents are generally poorly designed which fail to, inter alia, facilitate the patenting and commercialization process for inventions.

Technical and Vocational Training: There is a wide network of vocational and technical institutes throughout the country. The output and outcome of these institutes and the graduates they produce for the market fall much short of the market or industries' requirements. Technical Education and Vocational Training Authorities (TEVTA), provide only low-end skills without market research to identify the skills-technical-competence mix required by the industry to design the course work and curricula accordingly.

The Link and Connection between the Knowledge Infrastructure and Industry: To aggravate the situation, the links between the Pakistani knowledge infrastructure and industry are very weak. The landscape is characterized by fragmentation and incoherence. The industry and academic institutes generally operate in isolation. As discussed earlier, Pakistan's universities have poor research infrastructure and capability and most of their research does not have any industrial relevance.

The number of fiscal and financial incentives for stimulating

industries' demand for investments in technology development are very few which discourages the private firms from improving their S&T capabilities.

In summary, the qualitative mapping of Pakistan's NIS shows its system to be quite weak. Connectivity and linkage are sine qua non to muster creative synergy for technological advancement and innovation. There seems to be no commitment to foster and forge these links. The prevalent culture in fact stifles attempts, if any, to achieve this creative synergy through much-needed linkages and connectivity. The situation is no different even at the intra industry level. The linkages between the producers, the actors and entities along the value chain and the users in Pakistan are very weak and, if at all, just at the nascent stage.

28. The Digital Divide

There has been a phenomenal increase in the digitalization of the world in recent years. It is estimated that by the end of 2025, global data creation is projected to grow to more than 180 zettabytes (one zettabyte is equal to one trillion gigabytes).[9] The rapid pace of data assimilation, increasingly high demand for digital technologies in the wake of globalization and the surging need for cost effective service delivery are, among others, the major drivers of this phenomenon as also of pace and scale of innovation and technological advancement.

However, the digital divide and the digital inequality across the globe is one of the major challenges to be addressed. The United States and China themselves account for 75% of all patents related to block-chain technologies, 50% of global spending on the Internet of Things (IoT), more than 75% of the cloud computing market and as much as 90% of the market capitalization value of the world's 70 largest digital platform companies. The rest of the world, particularly many countries in Asia, Africa and Latin America, are significantly behind and have failed to bridge the digital divide and inequalities with consequent negative impact on learning, education, skills and opportunity (social, economic, cultural).

Digitalization helps a country to embark on digital innovation which essentially facilitates the implementation of modern digital technology like IoT, AI, big data, IT tools etc., to develop integrated and automated solutions for productivity enhancement, efficiency gains in businesses etc. It also gives a boost to optimizing internal processes, improving responsiveness and communication and monitoring and tracking progress for delivering new business models, collaboration, content management and social networking. Developments in digital technology also unfold many new opportunities for innovations to design new products and services. Although significant gains have been achieved, the situation in Pakistan is far from satisfactory. The UNDP Pakistan National Human Development Report 2020 with regards to digital inequality reveals that only 45 % of people own mobile phones, and just 17 % use the internet. Merely 46 % of Pakistan's population has access to 3G/4G services.

However, internet use in Pakistan is gaining huge momentum as 82.90 million people use internet which increased its penetration rate to 36.5 % of the total population.[10] It now ranks 20th in the world on the Internet use. The country has 5 broadband internet providers and 10 Digital Subscriber Lines (DSL) and four major cell phone providers which, in order, from most to fewest subscribers are: Jazz 69.24 million; Telenor 48.94 million; Zong 40.12 million; and Ufone 23.48 million. According to the Pakistan Telecommunication Authority, the overall tele-density was 85% in 2021. However, the knowledge and skills needed to utilize technology especially for education, health, careers, business opportunities or personal and professional growth continue to pose a major problem. This lack of knowledge to make use of ICT invariably widens the digital gap, with benefits limited to a select segment of society. Ironically, the top five apps used in the country are related to social networking and entertainment which means that access to ICT is not being converted to attain and avail education, e-commerce, financial solutions, healthcare, business opportunities, access to government services and empower citizens and consequently to scale economic growth.[11] Indeed, Pakistan falls behind most of the countries in terms of absorption of IT and IT enabled services owing, inter alia, to the lack of inclusiveness of the

digitalization process. This denies the country the ability to use and deploy technology for innovation, technological development and socio-economic uplift. More specifically, this lack of inclusiveness stems from:

i. The digital and literacy and linguistic divide (English being the primary user language) due to social and economic barriers based on gender, age, disability etc., or lack of technological competitive advancement to use IT and mobile platforms for economic gains and the poor quality and spread of connection and related services;

ii. Affordability and the pricing distortions and investment dictates due to the rapidly changing dynamics and advancements in digital technology and economy;

iii. Inadequate institutional capacity to widely apply ICTs, especially in education, health and delivery of social services preventing the poor from transcending geographic barriers and avail education, health and other services from distant and remote locations;

iv. Weak judicial system and enforcement machinery regarding Intellectual property rights (IPR) protection, consumer rights and arbitration procedures which discourage investment in research, development and dissemination of technology thus constraining creative activities such as invention, design, know-how, software code/solutions, trademarks etc.;

v. Lack of interest of the major technology houses of the world to invest in Pakistan, outsource their development work, promote incubating startups to create viable and profitable businesses, and, help steer the IT sector inPakistan to the next level for becoming Inclusive Digital and Knowledge Economy;

vi. Low level of awareness and knowledge in people, SMEs, social sectors and broader government apparatus of the full potential of ICTs as an enabler of sustainable human development and lack of deployment or use of ICT and its broad range of tools to integrate

the knowledge and communication dimensions in the development process, especially for poverty reduction, greater empowerment, job creations and security.

vii. The need to establish additional Technology Parks beyond the existing 14 around the country especially in major metropolitan areas and suburban centers and to accord high priority to R&D in ICT sector both in the public and private sectors;

viii. Addressing the gender-based digital divide especially when according to a study, 40 % of female users require permission from male family members to make calls; only 36% women compared to 78% men own cell phones;[12] the domination of the slowly evolving digital economy by men denying more than 50% of Pakistan's population the equal opportunity to harness the economic potential of the digital economy; and

ix. The regional disparity especially the remote areas inflicted with multidimensional poverty in the range of 70-79% with zero or minimal level of connectivity to broad-band networks;

Like many other policy frameworks, Pakistan also enacted a Digital Pakistan Policy (DPP) in 2018 with a view to fully benefiting from the emerging dynamics of a knowledge society and knowledge economy. It intended to enable the country to, inter alia, access the expanding market of software development, improve business processes and stimulate outsourcing and freelancing. The vision was "to become a strategic enabler for an accelerated digitization eco-system to expand the knowledge based economy and spur socio economic growth". The policy objectives included digital inclusion, pursuit of holistic digital strategy, sectorial digitalization, e-commerce and e-governance enhancement (e-Agriculture, e-Health, e-Energy, e-Justice, e-ICT education). It also envisaged the empowerment of youth and women, promotion of innovation (including collaboration with international partners to boost innovation and entrepreneurship), and encouragement of incubators and startups for

development of new technologies and applications. The establishment of specialized innovation centers for FinTech, AI, IoT and Robotics in major cities of Pakistan figured prominently in the DPP.[13] Numerous initiatives e.g., digitization projects, research and innovation, package of subsidies and incentives including international certifications were intended to support IT industry. In addition, internships and trainings, 100% equity ownership, 100% repatriation of capital/dividends, tax exemption on IT & its services export revenues, tax exemptions to startups and subsidized rates for establishment of Software Technology Parks to promote IT R&D and innovation were put in place to facilitate the IT industry.

However, while the policy delineated roles and responsibilities, its implementation faltered on account of lack of funds and technical expertise. Instead, a new Digital Pakistan Vision was launched by the succeeding government in December 2019 for Pakistan to become strategic enabler for an accelerated digitalization ecosystem to spur knowledge based economy. The goal was to help the country compete in the digital market globally. The vision covered 5 strategic pillars:[14]

- Access and Connectivity to ensure universal access to all citizens to internet as a fundamental right and especially to under-served populations.
- Improvement of digital infrastructure to create the ability to do most daily tasks using smart-phones in a secure and faster manner.
- Introduction of E-governance that digitalizes intra-government operations and processes towards a paperless and efficient environment and also digitalizes the government services for citizens.
- Digital Skilling and Literacy that enables technical graduates to secure relevant jobs.
- Innovation and Entrepreneurship that provides an enabling environment for startups to flourish.

With the exodus of the government in 2021, the work on the vision has again been stalled reflecting lack of serious commitment of the successive governments to make use of digitalization for embarking on innovation, technology development and knowledge economy. The positive sign and driving force for accelerated digitalization, however, is that even in the absence of a stable policy environment and institutional support, the country ranks at number four for freelance development in the world with IT exports increasing by 70% during the preceding three years. These exports are likely to reach between $10 billion to $18 billion by 2028.[15]

The next Part, based on the foregoing descriptive and diagnostic analysis, suggests specific recommendations and way forward for instituting the National Innovation and Technology System in Pakistan.

Notes

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8 Foreign direct investment (FDI) in Pakistan - International Trade Portal (lloydsbanktrade.com)

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11 Jehan Ara: The founder & CEO of Katalyst Labs and the former president of P@SHA, and founder of TheNest I/O.

12 Women and Mobile: A Global Opportunity," GSMA Mobiles for Development and the Cherie Blair Foundation for Women, January 2010. Available at http://www.gsma.com/mobilefordevelopment/wp-content/uploads/2013/01/GSMA_Women_and_Mobile-A_Global_Opportunity.pdf

13 Digital Pakistan Policy 2018

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15 International Bar Association https://www.ibanet.org › pakistan-it-and-ites-export

Part IX: Recommendations and Way Forward

Pakistan is confronted with colossal development challenges externally posed by a highly competitive and inter-dependent world, and internally manifested in the sluggish economic growth, widespread incidence of poverty and balance of trade and payment deficits. The country needs to re-define and re-design its economic development model and initiate a journey towards sustainable development. STI oriented growth will be the only viable option to achieve global competitiveness and sustained economic growth. A plethora of empirical studies has shown a positive relationship between economic growth and innovation and how STI development has helped economies across different parts of the world to achieve stable and sustainable development. A robust NIS was distinctively a common feature of their economic journey. As such, it is extremely important for the decision-makers of the countries desirous to economically leap forward to understand the criticality of establishing a vigorously strong NIS with a view to enhancing technology adoption and innovative performance.[1]

The situation in Pakistan, as revealed by the analysis and the challenges documented in the preceding chapters, clearly depicts that the innovation and technology environment, outlook and system are in a state of disarray and disorder across all sectors and tiers: macro-sectoral, sub-national and individual institution-entity level. The flaws and weaknesses of the system find recurrent expression in all its dimensions e.g., technology generation and transfer, knowledge infrastructure, R&D capability, innovativeness of the industrial sector, the I&T hesitant culture pervasive in the universities and public sector. NIS in Pakistan can best be described as a fledgling system which once was very vibrant in 1960s but due to persistent neglect receded to a regressive status quo-oriented apparatus bereft of any appetite for innovation and technological advancement. Though in between, sporadic sector specific and individual

institution led efforts were made to benefit from the technological advancement e.g., Telecom, Banking, Automotive, Defense etc. A collective and planned effort spearheaded by the government in close conjunction with the knowledge generating university and research system and private sector is the key and kernel to resuscitate and reconstruct the NIS. This will enable the country to embrace the knowledge-economy paradigm and avail the resultant productivity and wealth gains as a source of social and economic development. Pushing the innovation agenda in Pakistan, as such, can be a game changer for the country and leapfrog the country to regain its once proclaimed position as the Asian Tiger.[2] This is credibly attainable, especially in the wake of the recent rollout of the CPEC and the establishment of SEZs in the country. There is huge potential for Pakistan to become a part of the regional supply chain and indeed global production network and gain from the accompanying benefits of technology transfer, improvisation, generation and diffusion and innovation.

It needs to be realized at the same time, that the technology development and innovation processes are evolutionary, unpredictable and risky. The highest level of commitment and resolve is therefore, a condition precedent to guide and sustain structural changes in the economy and to be able to pursue stable and steady course. This commitment is a prerequisite to make up the massive technology-deficit and catch-up for a smooth transition to a knowledge economy, and transform the existing S&T system and infrastructure into an asset that drives value addition, generates wealth and foster competitiveness in the global market.

For this purpose, Pakistan needs to reform the entire S&T landscape with a view to instituting a robust and efficiently functional STI system which ensures in-built linkages and synergy among the major actors and entities i.e., the government, military, private sector and university and research system. The collective and collaborative operation of these entities into an institutionalized system will provide a much-needed impetus to fully harness the technology and innovation potential.

It will bolster both the adoption and improvisation of the imported technology as well as the generation of new indigenous technology and innovation for diffusion and dissemination across the country.

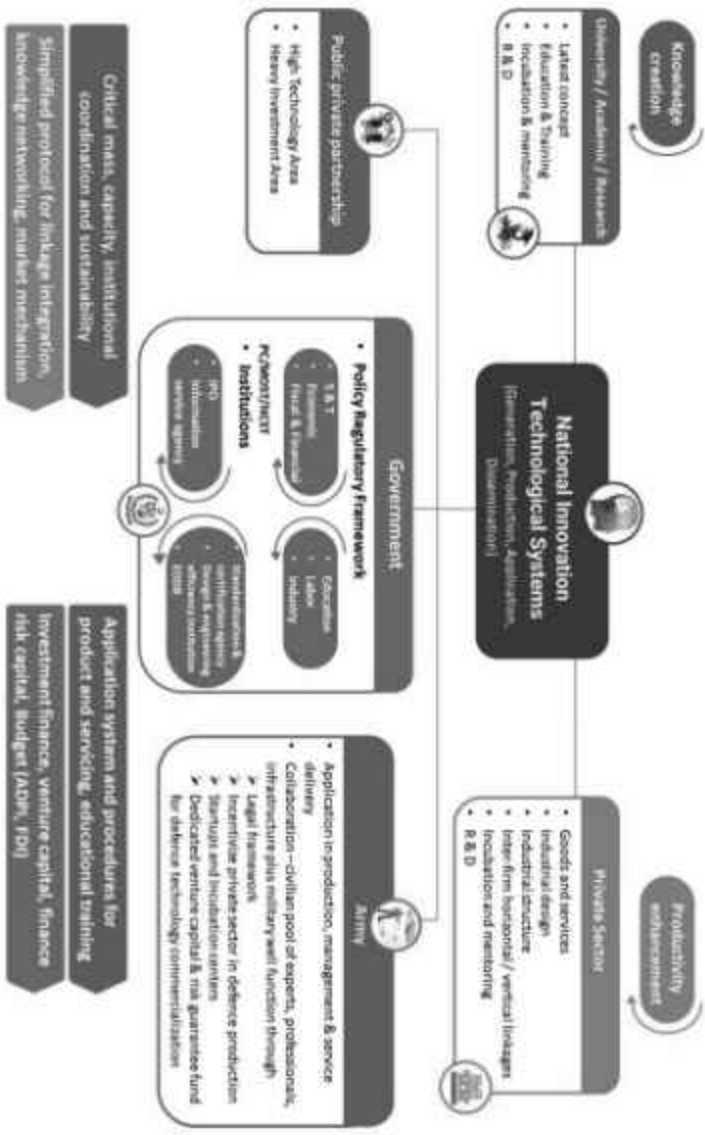
Before, however, elaborating on the structure, configuration and implementation framework of such a system, it may once again be underscored that the current scholarship in innovation studies has been deeply influenced by the NIS framework pioneered by Freeman and Lundvall. This framework provides a solid basis for conceptualizing and putting in place a robust STI system to enable a country to embark on knowledge and technology-led growth. Accordingly, the framework being proposed for Pakistan, immensely benefits from Freeman's and Lundvall's model and contextualized to respond to Pakistan specific situation. It has accordingly been designed and designated as the National Innovation and Technology System (NITS). The choice for NITS coinage essentially emanates from the recent evidence on sequential and concurrent development of technology and innovation as in the case of China where technological progress was a precursor to innovation advancement. The relevant literature clearly postulates that technology is indeed the conversion of science into artifacts that can be used to meet human ends while innovation, whether incremental or radical, leads to upgradation of technology for improving the utility of the artefacts as the human demands get more and more complicated. For a low middle income country like Pakistan, technological progress is thus equally important as innovation in order for it to leapfrog and catch up. Hence, the rationale for entitling the system as NITS is to signify and underscore the concurrent importance of technological advancement and innovation progress and the conjunctive use of the two terminologies together.

29. The Conceptual Framework of the National Innovation and Technology System

The following conceptual framework based on the theoretical perspectives, the analytical work both quantitative and qualitative, and the fundamentals associated with the system of technology and innovation,

illustrates the schematic for establishing a robust National Innovation and Technology System in Pakistan (NITS). The framework envelops the major actors and entities in the technology and innovation eco-system and proposes a viable and holistic structure and organization to ensure efficient functioning of the NITS to guide, strengthen and steward innovation and technology development processes in the country.

Figure 19: National Innovation Technology System



As is evident from the above figure, following are the essential and intertwined building blocks of the NITS:

- Government as the pivot has the responsibility to create a conducive policy and institutional environment and make programmatic interventions especially related to the necessary infrastructure development for technology and innovation;
- The private sector has to play an inevitable role in technology assimilation and generation and innovation to achieve productivity enhancement, create wealth and resources and accelerate economic growth;
- The university and research system constitutes the linchpin for knowledge and technology generation, development of technology and innovation driven integrated solutions through R&D, and linkage and connect with the private sector;
- The army, given the capability which it has developed over the years in terms of expertise and infrastructure for technology development and innovation, needs to share and institutionalize the spill-over of its technological gains to the civilian side and institutionalize collaborative R&D programs.
- The public-private sector partnership forms an integral part of NITS to foster R&D initiatives, especially in high-tech areas which require initial heavy investment and promote eagerly receptive I&T culture and ethos.

A fully functional NITS not only reinvigorates and helps streamline the upstream policy, legal and regulatory frameworks but also propels the alignment and calibration of the related institutions for impact-oriented collaboration for knowledge creation, innovation and technology generation and diffusion. Besides, it incentivizes the initiation of downstream programmatic interventions for the development and diffusion of technology and innovation. It however, a priori, entails:

putting in place a critical mass of expertise and human capital through investment in higher learning and technical training; ex-ante financial arrangement including the availability of venture capital and guarantee funds; and, simplified and efficient systems and procedures to facilitate smooth and effective linkage and integration of the troika of government, universities and private sector inter se and with the market. NITS indeed lays down the foundations of transforming the existing systems and structures to institute knowledge and entrepreneurial economy.

Against this backdrop, the following core components are proposed for the Pakistan National Innovation and Technology System to steer the country towards embracing the knowledge economy.

a) Vision

A compelling vision for the NITS is sine qua non to drive and direct a national commitment *en masse* - of its people, the state organs and R&D and knowledge institutions for technological advancement and innovation. This collective commitment will ensure a smooth transition to the knowledge economy and evolution of much-needed technology savvy ethos. The vision could be:

"Developing Innovative Pakistan" to evolve and transform the technology and innovation ecosystem to:

- enable the citizens, especially the youth to harness their full potential to exercise and expand their development choices;
- stimulate industry and private sector businesses to gain global competitiveness for accelerated growth especially exports and for wealth creation;
- revitalize the R&D endeavor in research institutions and universities system to generate knowledge, expertise and technology; and
- forge an inextricable linkage between the troika of government, industry and higher learning institutions and universities so that Pakistan embarks on the pathway to sustainable economic and human development and distributive justice".

A strong political ownership, commitment of the university and research system and active engagement of the private sector expressed in terms of necessary investment in the adoption, diffusion and indigenization of available knowledge and technologies is the condition precedent for concretizing this vision into reality. The ownership at the highest level in the longer run will invariably translate into creation of wealth through technology and innovation spurred productivity enhancement which, inter alia, could be apportioned steadily and incrementally to advance and sustain S&T and R&D effort for retaining a competitive edge. This will ultimately lead to the maturation of a virtuous cycle of S&T-led growth for the equitable development of Pakistan. *"Developing Innovative Pakistan"* implies value addition, an increase in exports, increase in GDP growth and sustainable human development.

b) Charter of Innovation

Policy consistency and stability in the domain of S&T and associated sectors is the first and foremost prerequisite to drive technology and innovation led economic growth. More than three decades of experience of the recently emerging economies like China, South Korea, Singapore, Turkey and some others countries speaks volumes of the imperative of political and policy stability in this regard. Pakistan must, therefore, ensure sustained policy continuity through a national consensus to foster technology development and innovation with a view to achieving accelerated economic growth. This will entail inclusive articulation of a "Charter of Innovation" at the national level, agreed to by all the political parties in the parliament, much beyond the political myopia of narrow interests. The consensus and national unity to technological advancement irrespective of the change in government or political leadership, in due course, will elevate Pakistan among the top 50 innovative countries in the world with research, innovation and technology at the forefront to lead economic growth and development. The major objectives of the Charter could be to:

i. sensitize country's leadership and seek ownership of political parties

of the importance of S&T and innovation and for STI policies;

ii. ensure consistency and stability in policies related to S&T and innovation and allocate adequate human, technical and budgetary resourcesfor R&D, especially for development of technology and innovation; and

iii. initiate and sustain a unified national drive and sense of priority for S&T and innovation involving, in particular, the private sector businesses, university and research entities and army authorities.

For this to happen, the political parties need to drive and inspire innovation culture in the country and contribute to the overall S&T development for the realization of the vision of *"Developing Innovative Pakistan"*.

c) A Dynamic S&T and Innovation Approach

The Model for Technology Development: Pakistan should shun the linear model of innovation that advocates a step-by-step growth from basic science to technology and innovation. This model has become obsolete and is no longer workable. Instead, the country should embrace the emerging dynamic, cyclical, and highly integrated model of innovation-led growth followed by the lead countries for S&T advancements in terms of methods, priority areas and pace of technology development and innovation. The technological competition and race between the USA and China reflect the differences between the old model and the newly evolving phenomena and approaches in technological advancement. More specifically, China invested approximately US$16 billion in 2022 (latest data) for R&D in artificial intelligence but is projected to capture a market size of US$154.80 billion by 2030.[3] In comparison, the USA invested US$200 billion in AI research and development in 2023 (latest data), with an expected market size of US$826.7 billion by 2030.[4] This means that China manages to create almost ten times market size of its R&D investment in AI whereas USA gains are estimated to be 4 times. The same technology approach serves in e-commerce, digital payment, high-speed railways, renewable energy, and

robotics. China also invests much less than the US in basic sciences but earns much more than the US. What gives China a competitive edge over the US is direct investment in the industry to buy, reproduce, produce and quickly capitalize on technology through commercial success compared to the US long cycle of investment in technology following the bureaucratic process. Pakistan should replicate the Chinese model and simultaneously invest in technology and innovation education to produce quality human resources and expertise as well as in technology adoption, diffusion and commercialization of available technologies through startups and large-scale enterprises. The motto should be to whole-heartedly commit to: "the fastest technology application and commercialization invented by anyone".

S & T Sector to Galvanize GDP and Exports' Growth: The role of S&T needs to be assessed, planned and executed with the growth of GDP and exports as primary goals. Pakistan at the initial stage of development may not just get involved in inquiry- based science that leads to creation of new knowledge and exploring the unexplored without much attention to the applied and practical aspects of research. The limited resources need to be consumed wisely to generate more economic activities and create wealth. The S&T plans and projects must target wealth creation through applied research and experimental development and the accompanying investment must be measured against economic results and outcomes in the form of import substitution, export increase or contribution towards the GDP. The priority should be accorded to those projects and industries that can yield economic results in 3-5 years.

Entrepreneurial Diplomacy: The new approach also entails a transformation of the diplomatic efforts to "entrepreneurial diplomacy" to mandate Pakistan's embassies and missions to strive for demand driven technology transfer and import in Pakistan. While the diplomatic staff needs to be fully briefed and trained all along in their professional career in this endeavor, a measurable performance appraisal system should be introduced to judge the role of embassies in technology and know-how

transfer.

The following figure 20, based on the vision "Developing Innovative Pakistan" captures the ingredients of entrepreneurial diplomacy.

Figure 20: Entrepreneurial Diplomacy

30. Guiding Principles

- A vibrant, consistent and futuristic STI policy regime is sine qua non to ensure a conducive and viable environment for technology and innovation. This regime should, inter alia, strengthen and improve the efficiency and effectiveness of the state apparatus to support the industries through adequate infrastructure and facilitative regulatory framework including anti-dumping measures to protect from foreign unlawful invasion of competitors. The financial incentives for import of new technologies, raw materials, machinery, startups and new ventures and the dedicated research funding including subsidized R&D to set up pilot units and develop demand driven technologies should constitute a key part of the policy regime.

- The major actors such as firms, government and knowledge infrastructure must play their respective roles to improve and strengthen the overall performance of NITS. The universities together with the firms should conduct R&D to develop innovative products that can be commercialized and start up new businesses to

exploit new science produced by the knowledge infrastructure.

- Strong links between the government, enterprises and public and private knowledge infrastructure are imperative for a robust NITS. Research investments alone are not enough and Pakistan like other countries which have been successful in catching up along with public investments needs to deploy "coupling mechanisms." These mechanisms may consist of planned actions and policies to link the country's scientific institution, education systems, R&D facilities, engineering, businesses, and markets to each other. Also, the gap between the government and knowledge infrastructure and firms and knowledge infrastructure needs to be reduced immediately.

- Intellectual Property Organization (IPO), established in 2005, which still does not have a critical mass of properly trained professional staff to assess and evaluate patents should be strengthened. Similarly, the Intellectual Property Rights (IPR) policy for innovation should be updated and strictly enforced. Without a proper IPR and associated standards and enforcement for quality production, it is unimaginable to think of any S&T advancement.

- The young population and human capital provide Pakistan with a huge demographic dividend and is a key strength which Pakistan must leverage to develop and man the S&T oriented sectors. Developing S&T and innovation ethos will, a priori, require integration of the youth and investment in the human capital. For this purpose, the education sector must be accorded top priority. Myopic and short-term policies for education especially STEM need to be replaced with a long run and sustainable higher education policy to promote analytical and critical thinking right from the beginning (elementary school level) of education and progressively elevate to availability of well-working research environment in the universities and institutions of higher learning. It may be noted that the countries which have invested more in the development of their

human resources through increased and improved opportunities for education and research are teasing the frontiers of STI.

- The technical and vocational education system must also be strengthened side by side by adopting the best international practices. Technology transfer from high performing firms and innovation cannot take place if Pakistan's critical mass remains technically illiterate and uneducated.

- Population planning with emphasis on bridging the digital divide must receive the utmost attention to ensure that the GDP growth engendered by STI is not nullified by the rate of population increase and exclusion of women and deprived segments from STI gains.

31. The Roles, Responsibilities and Relationships

The roles and responsibilities of the major actors and entities of NITS should be clearly spelled out to ensure its smooth functioning and realize intended objectives as follows:

(a) Government

All-inclusive Ownership

The entrepreneurial mindset is a common thread and a fundamental feature for orchestrating all-inclusive ownership of the major actors and entities of the NITS. Innovation and technology thrive in an entrepreneurial culture which helps identify and create opportunities, enhances productivity, adds value, and keeps the value improving over a period of time. Government invariably plays the most dominant role in fostering and cultivating an entrepreneurial ethos. An entrepreneurial government is status quo averse, catalytic, competitive, responsive, results-oriented and market-driven. However, as earlier stated, S&T and innovation have not figured notably on the priority agenda of successive governments especially since 1970s for economic transformation of Pakistan with technology and innovation as the engine of growth. The

decades of lost potential have significantly impeded the efforts to achieve sustainable development and neither helped the country integrate with the global production networks and value chains. If the country has to catch-up, bring about an accelerated rate of growth and regain competitiveness in the highly globalized world, it has to commit itself to adopt and promote IT, knowledge and innovation led economic paradigm. The pre-condition for the purpose is to establish a robust NITS with inclusive ownership of the political governments, private sector and industry and the university and research institutions. This all-inclusive ownership is the kernel to nurture a technology savvy, entrepreneurial and innovation culture as illustrated in the figure 21.

As is evident from below figure, entrepreneurial governance is one of the fundamental pillars which, inter alia, envisages the entrepreneurial role of the government permeated in all the tiers down to the district level and across all Ministries.

Figure 21: All-Inclusive Ownership NITS

Strengthened S&T governance and entrepreneurial diplomacy are key to ensure seamless vertical and horizontal connect and linkage in the scientific knowledge and technology generation and assimilation effort. A revitalized and effectively functional National Council for Science and Technology under the Prime Minister can institute and cement political ownership. The training of parliamentarians on S&T, visit of parliamentarians on S&T setups in advanced world and establishment of Parliament and Senate Committee on technology and its diffusion will help ensure that technology and innovation dimension is fully reflected in the government policies and frameworks. The technology led growth thus becomes an innate part of the political agenda.

The higher learning institutions and universities have to bring about a transformational change from the traditional obsolete pedagogy to entrepreneurial academia with a focus on applied teaching and learning, incentivizing faculty and students' startups and strengthening their R&D systems. Through extension and outreach programs, they should set up Rural Technology Centers geared to developing integrated technological system based on the local production system and needs in synch with the entrepreneurial and technology-led government.

At the same time, the private sector has to shun the inherent technology- shy culture and mutate steadily but consistently to reshape the entrepreneurial industry. Technology transfer has to constitute an integral part of foreign direct investment, especially for the establishment of new industries while technology improvisation and diffusion should permeate all across and at all levels in the operational milieu of the industry. In view of the strong R&D system and infrastructure of the military and defense establishment, a well-built link and connect should be made obligatory to facilitate technology and innovation capability spill over to the civilian side and commercialization of military R&D and technological innovations, knowledge products and services.

The cumulative impact of this all-inclusive ownership will translate into a well-functioning NITS and consequently, rapid GDP growth, boost

to exports, meteoric productivity increase and wealth creation. This will in turn pave the way for sustainable and equitable development to realize the objective of a prosperous and progressive Pakistan.

Policy Framework: In Pakistan, policies related to science, economics, and technologies have not been given due attention to serve the respective sectors and harness sectoral synergies. The partial efforts of academia and industry or government and industry to collaborate without a conducive and driving environment tends to falter and widen the trust deficit. The government of Pakistan has to come up with conducive policies and good incentives to ensure business transformation through the triple helix model.

For this purpose, especially a holistic and consensual STI policy framework covering measures such as clearly laid down objectives, establishment of an overarching institutional mechanism, strengthening of the IS, synergizing government, industry and academia linkage, encouraging innovation at the firm level and supporting knowledge provision is fundamental to developing a robust NITS and pave the way for knowledge economy. MOST which is the apex body for STI in the country, should institute a regular dialogue between the public and private sector and the knowledge generating institutions and university system for policy development and adjustment, its execution and monitoring. A collective cabinet and parliament backed STI Policy along with enabling legislation with the engagement of all the stakeholders and institutions within NITS is an essential prerequisite to provide direction and define the respective roles and responsibilities of all the major actors in the NITS eco-system. The policy has to be context specific and must be tailored according to the priorities and requirements of the country and also be receptive to the role of the informal sector in innovation and technological progress. The latter is a major segment of the economy and could be instrumental in expediting Pakistan's effort for successful catch-up and achieving sustainable economic growth and development.

In addition to STI policy, complementary and substantively

relevant and synergistic policy and regulatory frameworks and environment including Education, Fiscal, Labor, Information and macro and sectoral development plans must also be provided with an embedded focus on ST&I and R&D. This environment should also incentivize investment, financial allocation, venture capital and guarantee and financial risk capital. The education policy, in particular, should be reformed through an all-inclusive process with scientific knowledge, entrepreneurship and skills development at its core. Under this policy, integrated national level plans and programs for skills-competence development should be formulated and assigned to the respective ministries and departments for implementation.

The international experience of countries like China, South Korea, Singapore, etc., also suggests that a well calibrated STI policy, as adopted in these countries, can be very helpful in driving up the growth rates in Pakistan as well.

Institutional Support: The role of Pakistan's government in advancing S&T in the country has been extremely poor. In the absence of a strong institutional lead, the innovation agenda of the government is characterized by confusion and*ad hocism*. MOST is the lead technical Ministry which has to steer technology development, diffusion and innovation in the country. It can drive the performance of other ministries of the country as well but even the majority of the key S&T agencies working under MOST lack ample funding with the result that only meagre resources are allocated to encouraging technological advancement and innovation. Along with MOST, the National Commission for Science and Technology (NCST) headed by the Prime Minister is the major custodian of S&T in Pakistan. The NCST has been nonfunctional since long having no regular meetings and/or progress reviews on the technology development front. The failure of S&T in Pakistan is due to the inactivity of NCST. The Prime Minister of Pakistan must provide the necessary leadership to S&T by attaching utmost importance to MOST and activating NCST by chairing a minimum of two meetings of the Commission

annually.

The related institutions particularly those dealing with the IPRs and Standards and Certification Regulations should be made effectively functional to improve and standardize design and engineering efficiency. They must be strengthened and provided with at least a critical mass of technical expertise, HR and organizational capacity, infrastructure etc., to implement these upstream frameworks.

Surprisingly, despite government's various recent growth strategies emphasizing the role of innovation in improving productivity, very little is being practically done to foster innovation to unlock productivity deficit in Pakistan's industries and generate satisfactory levels of economic growth in the coming years. As opposed to Pakistan, improvements in innovation capabilities in recent years in emerging economies such as Brazil, Russia, China, India and South Africa have been quite good and contributed to the overall growth of these countries.[5]

It is, therefore, recommended that all ministries and departments at the federal and provincial levels must transform their functional orientation to imbibe technology adoption and diffusion within their mandated sectors and areas of activities. More specifically:

- Each Ministry must set up a technology adoption and diffusion unit which should be manned by S&T graduates and professionals for technology planning and adoption. This unit should stimulate development of technology and entrepreneurial culture across all the functional domains of the ministry and its attached departments;

- The Ministries should institute incentives and rewards based on appraisals of technology outcomes, international or national technical collaboration and related performance metrics;

- S&T operational budget should be steadily increased to provide at least 2% of the budget for S&T related development and diffusion and linkage with the counterpart industries especially those related

to imports and exports;

- At the divisional and district levels, Commissioners and Deputy Commissioners should strengthen their Planning Units through training and capacity building of staff to drive the technology adoption and diffusion initiatives and help establish technology clusters and specialized zones by incentivizing and partnering with the Chambers of Industry and local universities. They should develop technology-led programs for enhancing the district level quality of life index, human development index and environment and sustainable development parameters.

- A central assessment system spearheaded by MOST should be introduced to gauge Ministry's performance in terms of international and national tech-collaborations, incentive structure for new developments and rewards.

Institutional Coordination: The lack of coordination and synergy among various actors i.e., inter-ministerial and inter-organizational to integrate and harmonize their S&T development plans has been one of the major failures of technological advancement. The absence of an effective coordination mechanism has caused excessive duplication of resources and wastages. Complete S&T resource data is not available with any organization in Pakistan. MOST as a Federal S&T coordination unit must mobilize and drive all stakeholders towards the goal of S&T development. Improved coordination function to eliminate the disconnect, fragmentation and isolated initiatives will be a condition precedent for maximizing the ST&I dividends.

Incentives for R&D: Well-targeted R&D subsidies should be designed to spur technology development and innovation. Rodrick (2004) has given three principles for subsidy design viz., embeddedness (collaboration between public and private sectors), carrots and sticks (willingness to invest but also withdraw from subsidies that are not working) and accountability.[6] These principles are not being practiced in

Pakistan as subsidies once granted tend to stay for a long time. The follow-up and accountability mechanisms are very weak which need to be strengthened. In this connection, the role of IPO needs to be buttressed for tightening and controlling infringement of IPRs. Potential IP producers such as universities, firms and R&D institutions must be incentivized and made aware to produce IP strategically so that violation of any IPR can be effectively countered.

The government should also remove fiscal disincentives such as high tariffs for import of technology following the experience of Bangladesh for import of machinery for the textile and garment sector. This is likely to encourage R&D, innovative behavior and technology acquisition. Government should also enact and implement a set of enabling procurement policies to support the uptake of innovative services and products and exploration of new markets particularly in the high public interest areas such as the energy sector.

Pakistan also needs to encourage entrepreneurs by establishing more incubators and technology parks. A model based on public- private partnership and close collaboration of knowledge infrastructure may be a good option to start with. Ease of doing business environment, at the same time, should be improved to support tech investment and attract FDI for technology-led industries in each district. The expatriates should, in particular be encouraged through fiscal and financial package (tax relief, repatriation of profits, quota in SEZs etc.) to bring advanced technologies and investment in the country.

(b) University System- Entrepreneurial Academia

The emphasis and major thrust of the universities and research institutions should be on knowledge creation, technology generation, innovation experimentation and development of technological applications, products and services. While R&D should be accorded high priority, academic institutions must shift the pedagogy to imbibe interactive learning, applied teaching and learning, assimilation and

analysis of the latest concepts and knowledge frontiers and technical, scientific and creative education and training. The establishment of incubation centers and mentoring of students by industry should be an intrinsic and indispensable component of all the higher learning institutions and universities in Pakistan.

Entrepreneurial Culture: The universities also need to incorporate entrepreneurial teaching and research missions in their charter to be able to convert research into products and solutions for the industry. They should be encouraged to generate a wealth of financial resources through research commercialization, technology transfer and startups. More specifically:

- The faculty should involve itself in real life issues and applied projects in close conjunction with the industries and communities to identify and understand practical issues and problems for resolution. Proper incentive structure to reward the applied teaching, research and development of technological solutions should be instituted;

- The students should be required to do internships and spend good time in industry and communities during their studies to get involved in real life problem-solving exercises. Their assessment and evaluation should include applied learning and practical work in the field;

- Startups by students and faculty should be encouraged to develop technology and innovation receptive culture and for this purpose:

    - Faculty and students need to be facilitated to establish startups and provided with the necessary logistics and conducive environment for product development and business launch e.g., seed money in collaboration with the private sector, mentoring, tool kit on basic finance, marketing and sales to run ventures etc.;

- Support to the faculty and students for IPRs, contract drafting and agreements should be provided.

- Rural Technology Centers by Universities should be established to connect universities with rural development in Pakistan and for this purpose:

    - Each university should set up rural technology center within the districts and sub-divisions in the vicinity to drive grass roots technology diffusion through, inter alia, technology demonstration and application projects;

    - University should be provided with adequate funds to get subsidized rural-centered technologies imported for the rural areas from the advanced world.

Strengthening University R&D Eco-System and other Related Organizations

This will entail restructuring and better, autonomous and dynamic S&T governance in Pakistan free from bureaucratic control. This could be achieved through:

- Grant of autonomous status to universities for conduct of mandated activities independently without bureaucratic curbs and controls;
- The training of faculty, scientists and research staff for undertaking R&D projects and commercialization of research products;
- Integration with industry of S&T organizations;
- Financial incentives to the scientists and staff and profit sharing in tech commercialization and increase in their operational budget;
- Career advancement linked to the contribution and impact of technology developed or introduced;

Education, a Priority Sector and Linkage with the Industry: Pakistan over the years, and paradoxically without conscious policy decision, has managed to produce a large pool of scientists, engineers,

doctors, and technicians capable of assuming an active role in S&T. In order to harness this potential and make up the scientific knowledge and technology deficit and lag, the country should, as a matter of utmost priority, orientate the development planning to massively improve literacy and quality education at all levels. The focus should be on creating a high level of skilled human resources and expertise in STEM and scientific and technological fields and promoting applied research, innovation and technology solutions for the industry. This should be complemented by policy and institutional adjustment to encourage investment of entrepreneurs in indigenously developed products and processes[7] and to improve their productivity.

The demand for technology in terms of adoption and diffusion is weak primarily due to the absence of S&T conducive environment and the workforce supplied to the industry. A package of fiscal incentives to inspire the industry to invest in higher technical education, skills development and R&D is necessary to generate demand for technology development and diffusion. More specifically, it will involve the following measures:

- Establish Offices of Strategic Alliances and Technology Transfer in the Universities (extension of ORICs mandate) to develop strategic alliances with the Chambers of Industry and the industrial clusters and negotiate, initiate and launch collaborative and applied research projects; and marketing and licensing of their innovations, technology products and services;

- Maintain a close liaison with the industry to assess the recent skill level requirement of the employers, modify the curriculum accordingly, and, train graduates with the aim of making them *"Job Creators"* rather than *"Job Seekers"*.

- Designate champions from among the faculty as contact points to mobilize funds and sponsor technology driven research with the potential to achieve mutually beneficial technological outcomes;

- Create a financial window for mobilizing government, non-

government, donors and MNCs funds and sponsorships for technological development;

- Transform the Small and Medium Enterprise Development Authority (SMEDA) to become more vibrant, supportive and proactive in initiating policies and strategies for boosting entrepreneurial ventures and sharing latest global trends to inspire and guide the industry and policymakers;
- Attract large MNCs and their subsidiaries to engage in projects aimed at technology transfer-led FDI and for this purpose, incentivize access to finance for new business ventures.

c) Private Sector- the Role of Industry as Entrepreneurial Unit

As regards, the private sector, a high priority goal should be to gain productivity enhancement through technological intervention and innovation in the business processes technical as well as managerial and produce high quality-competitive goods and services. The private sector with enabling policy and institutional environment should not hesitate in devoting investment to the technology induced industrial re-design and structure and develop inter-firm- cluster- based horizontal and vertical linkages for technology and innovation diffusion and know-how dissemination. The medium and large industries should be extensively engaged in setting up the incubation centers and mentoring the startups in conjunction with the academic and research institutions. Most of the Pakistani industry is traditionally based on trading, packaging and formulation. The value addition based on technology is very little component of entire industry in Pakistan. The industry needs to be encouraged for technological upgradation and increased value addition for the significant increase in GDP and exports of Pakistan. The following specific measures are recommended:

(i) Technology Diffusion in the Existing Industries

Local Industry is extremely important for building strong NIS.

This should be achieved through:

- Diplomatic drive to bring technology from the developed and emerging economies for the local industry;
- Technology exchange and transfer agreements with developed nations and subsidized technology imports by using, inter alia, CPEC/SEZs facilities;
- A three-year tax credit for technologies' advancement in existing setup and a five year's tax credit for new technology-led plants making local transfer; and
- Zero interest loan for new technology or technology upgradation.

(ii) Technology Transfer through FDI

This could be stimulated as follows:

- Encourage high-tech firms to invest in Pakistan's market with technology transfer as an integral part of the investment portfolio;
- Ensure Ease of Doing Business to attract FDI;
- Demonstrate and validate policy stability, rule of law, good governance and legal and regulatory frameworks especially for contract enforcement.

(iii) Technology-Based New Industries

Technology-driven manufacturing units can play a major role in introducing and establishing latest technologies in Pakistan through inter alia:

- State investment in IP and technology licensing;
- Financial grants for licensing new technologies;

- Zero interest finance for new technology startups;
- Risk sharing for technology ventures in the areas of national interest; and,
- National appreciation program for startups and new ventures.

Business Transformation: Business and industry transformation, in view of the rapid technological development and competitiveness, is a prerequisite for the industry to survive and to be able to align with the market demand and avail the new opportunities through innovative interventions. Innovation and technology receptive culture indeed make them adequately responsive to the economic and social transformation of the society and country as experienced in the developed world and recently in emerging markets of Asia.[8]

In Pakistan, however, as pointed out earlier, the industry is not disposed toward a transformation process. For this purpose, academia and industry working together can enable the industry to benefit from the new ideas generated by academia and institutions of higher learning for business transformation and creating new value products. In turn, the industry can convert academic research and knowledge products into market-driven goods and services. Thus this close collaboration becomes mutually beneficial and not only helps industry transformation and secure the business life cycle but also stimulates academia to continue generating new ideas. This virtuous cycle once established also propels the industry for self-transformation to be able to sustain and remain relevant business. The transformation of IBM from a pure software company to a data management and data science company and Amazon for cloud services and Microsoft as a mobile company present eloquent evidence of industry responding to the market and emerging demand.[9]

Government is always at the center of the process of industry's transformation and technological development stemming from academic research in terms of putting in place a conducive environment and addressing all the impediments which discourage business transformation

and competitiveness. The more the environment is competitive and facilitative, the more is the incentive for the industry to venture into value additions and new products to respond to the global competitive market. The ultimate outcome is a win-win-win situation for the academia to generate new ideas and expand their frontiers of knowledge, the private sector to increase productivity, profit and wealth and the government to increase its revenues in terms of taxes, economic activities, employment, and other benefits for distributive justice. The following measures, among others, are recommended:

- The government should proactively create a conducive environment for industry transformation *en masse* (as opposed to sector specific), to respond to new business challenges and market needs through state policy and cementing in-built interactions and collaboration between the institution of higher learning and industrial sector to promote a dynamic and sustainable innovative eco-system;

- The policy directives, regulatory regimes and practical interventions must address the problems and capacity of the three major actors and their interplay simultaneously i.e., government itself, research and industry in the promotion of business innovation aimed at providing a framework to understand and promote local knowledge based entrepreneurship.

32. The Role of Army - Pakistan's Success in Defense R&D and Spill Over to the Civilian Sector

In Part IV of the book, the technological capability and expertise as well as extensive R&D infrastructure developed and acquired by the Pakistan military, over the years, has been briefly described. Some of the sophisticated defense systems indigenously developed, have endowed the country with the capability not only to defend its territorial integrity in case of aggression but also to create significant deterrence to prevent the enemy from venturing into hostile activities. However, no systematic effort has

so far been made to institutionalize or incentivize civil- military collaboration for the spill-over of the technological products, services and know-how for technological advancement of the private sector industry or learning from the defense experience or inculcate appetite for technology and innovation.

It is also evident that in its R&D endeavor, the military works like an established technology hungry industry and goes for the solutions to the problems through a creative combination of reverse engineering, innovation and new technology development. Pakistan facing serious challenges of defense, social, food and economic security may adopt this path of "dual use" technology-led development through civil-military nexus. The "dual-use" of technology and software can enormously serve civilian commercial interests e.g., the Global Positioning System, civilian use of nuclear technology in energy, health, food etc., sectors, though to be managed safely and securely through good governance and command and control structures and a strong degree of regulatory competence. In the agriculture sector, the technology could be introduced to protect food crops and kill weeds and insects and save the livestock form pests attack and infectious diseases and also from biological threats including those from pandemic diseases and bio-terrorism.

The advances made in AI through military R&D, could be deployed and applied in many complex civilian fields both in the production, management and service delivery and could be easily and pervasively integrated all along the technology's cyberspace e.g., in the health sector from detecting anomalies in samples during MRI scans, in the security sector for surveillance and monitoring to, inter alia, control crime and ensure peace and law and order etc. Some precision components like the image intensifiers used in night vision goggles and the focal plane arrays found in surveillance satellites and thermal cameras, could be deployed for several civil applications e.g., nature photography, medical imaging, firefighting, and population control of predator species. Similarly, ultrafiltration technology solutions used for military purposes

could be utilized for civilian purposes to desalinate sea and brackish water as well as purify polluted water for human consumption in urban areas- a problem which is becoming worse day by day.

In fact, ever since 1960s, the defense sector of Pakistan has witnessed consistent and sustainable R&D advancement. Significant results have been achieved in this sector with the production of state-of-the-art tanks, missiles and fighter aircraft. The Atomic Energy Commission has also successfully developed nuclear technology that has made the country almost invincible. Pakistan has also entered into the group of countries that export defense products. Some civil use of defense technologies has already been tried and successfully practiced in Pakistan e.g., lasers for agriculture, cancer treatment and infrastructure development. There is, therefore, a massive scope to promote dual use of technology in Pakistan.

However, the level of technological advancement achieved in defense has not been accomplished in the civilian sector of the country owing inter alia to: the abysmal performance of the higher education sector in the S&T domain and misplaced focus on teaching and publications irrelevant to local needs and demands; low priority to the technical education; inadequate resource allocation to higher education and science infrastructure, and, neglect of basic and technical education.[10] Lack of connection and synergy between the three major pillars of technological advancement and innovation viz., academia, industry and government which tend to work in isolation without mentionable collaboration or synergies further aggravates the situation. Pakistan military, to the contrary, has developed the in-built institutional capacity to link R&D with the well-articulated defense needs, aligned education and training to produce expertise and HR required for its R&D and arranged ex-ante funds to carry out its need-driven technological development and innovation endeavor.

The pre-conditions are ripe for forging the civil-military nexus in the R&D and technology development. There are relative strengths that

can be harnessed e.g., a massive pool of experts, scientists and skilled professionals in the university system, an industry intensely in need of productivity and competitive enhancement, extensive infrastructure of the engineering, science and technology institutions of higher learning etc., on the civilian side while military has already established a well-functioning R&D capability and network of its own R&D institutions and industry. What is required is the strong political will, commitment and the realization transcending beyond the myopic apprehensions of security breach to connect military and civilian sides as elsewhere in the world especially based on the successful experience of countries like South Korea and USA. This could be facilitated through mutually agreed protocols to ward off any misconception or apprehension of infringement of security and successfully effected step by step engagement e.g.: (i) joint identification of the technological problems to be addressed for technology development while at the same time working together to advance science education and need-based skills for creating the requisite HR capability; (ii) a well-planned and governed collaborative mechanism; inclusive and intensive end-user-beneficiary participation e.g., industry, government etc.; (iv) rigorous effort to develop, pilot and test the technological solutions; and (v) offer and attract private investment for production of the defense technology.

This synergy and collaboration will not only lead to the "spill-over gains" from the military to the civilian side but will also ensure the use of substantial "idle capacity" and waste of the military R&D complex and infrastructure and the optimal flow of the know-how and expertise to the benefit and developmentof the local industry and the civilian research outfits. Government should play the key role in cementing this link and nexus and for this purpose adopt the following measures:

a) Establish appropriate legal framework, procedures and protocol to connect and synergize civil-military collaboration for commercializing defense R&D and developing technologies needed by the industrial sector;

b) Attract and incentivize private investment in defense

technologiesas a profitable enterprise through defense technology commercialization;

c) Set-up startups and incubation centers to launch new ventures of defense technologies; and

d) Create a dedicated venture fund and risk guarantee-fund for defensetechnology commercialization.

This nexus will help Pakistan establish a robust and functional National Innovation and Technology System (NITS) to be able to embark on knowledge-economy as a development paradigm and to forge the much-needed government-defense-university system- industry linkage.

33. Implementation Framework and Intervention Model

The NITS implementation framework provides a simultaneous albeit phased approach of operationalization of the system in order to ensure an all-out collective national effort and commitment across all sectors and at all levels and tiers of government to realize the ultimate objective of embarking on technology and innovation led growth and knowledge economy. The framework serves as a holistic and inclusive system to ensure synergy and connect amongall the relevant actors and entities, their organization resources for R&D, the local context and market trends and growth target and monitoring of progress. The purpose is to fuel knowledge-technology-innovation-led sustainable growth by incorporating innovativeness into the DNA of NITS major players i.e., government including military, industry and universities-higher learning organizations. It should envelope the specific parameters to be pursued such as:

- Industrial and economic growth targets for the next 10-20 years;
- R&D and Innovation to achieve growth targets;
- R&D for identifying the demand, priorities and market analysis;
- R&D planning for product, processes, and infrastructure;

- Human resource development for the desired R&D-led growth;
- R&D for resource mobilization and financial sustainability; and
- R&D for monitoring of execution and growth tracking;

Against this backdrop, NITS should be deployed at three levels: federal, provincial and district involving industry, academia and all relevant institutions and entities.

a) Federal Level: The previous section amply describes the overall configuration, vision and roles and responsibilities of the major actors and entities of the proposed National Innovation and Technology System. The highest level of commitment at the federal level is sine qua non to establish a functional NITS and create a policy and institutional environment to ensure NITS's smooth functioning. The Planning Commission (PC) which is the apex financial and public policy and development planning and monitoring entity responsible, inter alia, for providing long term economic vision,[11] at the Ministry of Planning, Development and Special Initiatives and chaired by the Prime Minister should assume the overall role of overseeing NITS implementation. It may be added that PC is mandated to catalyze and pursue knowledge based economy.[12]

This oversight mechanism of PC is essential as the journey for economic transformation to knowledge economy of which NITS is the linchpin, needs to be steered by the highest policy, planning and decision-making body. For this purpose, the PC's oversight mechanism must formally include the leader of the opposition, Federal and Provincial Chambers of Commerce and Industries, two representatives of academia/HEC and the Provincial Planning and Development Departments in order to ensure unflinching national commitment for NITS functional and financial sustainability. PC should convene at least two meetings in a year to review NITS related progress and activities.

The actual implementation of NITS should be assigned to a revitalized National Commission for Science and Technology (NCST) in

tandem with the MOST. The NCST membership should also be enlarged to give representation to the Federal and Provincial Higher Education Commissions, Federal and Provincial Chambers of Commerce and Industry, Defense Science and Technology Organization, two representatives each from the renowned private sector and public sector universities recognized for STEM education as well as R&D activities, SMEDA and representative (s) of eminent think tank (s).

The NCST functional mandate should be expanded to include:

- establishment and efficient functioning of NITS; and
- forging strong linkage between government, industry, academia and military for R&D and innovation and technology development.

NCST should develop an execution plan for NITS implementation and meet quarterly for its monitoring. The execution plan will help the major actors and entities i.e., government/policy-makers, university system, research organizations, military and private sector to collaborate and embark on adoption of S&T and innovation and its integration in all spheres of social and economic development. It will also nurture a culture of inter-organizational arrangement for pursuing collaborative R&D, including research consortia and joint projects and research-related activities commissioned to universities by industrial clients, contract research, consulting, quality control, testing, certification and prototype development. The use of university labs and equipment by firms, business incubators, and technology parks located within universities on the one hand and the transfer of university-military generated IP (such as patents) to firms (e.g., via licensing) on the other should be regulated. At the same time, training of industry employees, internship programs, postgraduate training of students in industry and secondment to industry of university faculty and research staff should also be ensured to, inter alia, promote academic entrepreneurship. This linkage and nexus will propel increasing use of innovation and technology to achieve productivity gains, competitiveness, catch up with the advanced economies and shift to

knowledge economy for inclusive sustainable development.

The revitalized NCST, in particular, should focus on promoting, accessing and espousing:

(i) Innovation Led Growth through Technology Reservoir of the World

The support provided and an approximate number of patents held by the five biggest intellectual property offices in the world as of the end of 2021, based on available data include:

a) ***The United States Patent and Trademark Office (USPTO):*** The USPTO offers support for technology transfer and commercialization through various programs, such as the Patents for Humanity program and the Global Intellectual Property Academy. These programs provide training, assistance with patent searches, and support for licensing negotiations. According to its website, the USPTO issued over 400,000 patents in 2021. As of September 2021, the total number of patents in force in the US was over 11 million.

b) ***The European Patent Office (EPO):*** The EPO offers support for technology transfer and innovation through various programs, such as the European Patent Academy and the European Patent Network. These programs provide training, networking opportunities, and support for patent information and searching. According to the EPO's 2021 annual report, the EPO granted 139,000 patents in 2021. As of December 2021, the total number of patents in force in Europe was over 3.2 million.

c) ***The Japan Patent Office (JPO):*** The JPO offers technology transfer and licensing support to countries through various programs, such as the IP Acceleration Program and the Patent Information Program. These programs provide training, assistance with patent searches, and support for licensing negotiations. According to the JPO's 2021 annual report, the JPO granted 60,000 patents in 2021. As of December 2021, the total number of patents in force in Japan was over 4.4 million.

d) ***The Korean Intellectual Property Office (KIPO):*** KIPO

provides a range of support for technology transfer some of the successful technology transfer projects include; a bioenergy project in Indonesia to produce from palm oil waste to reduce greenhouse gas emissions; a smart city project and a water treatment project in Vietnam to improve urban planning and management and promote the development of the local ICT industry and to improve access to clean water and promote public health in the remote areas; a healthcare project and a renewable energy project in Myanmar for telemedicine solution to improve healthcare access and outcomes and a renewable energy solution to improve access to electricity in rural and underserved areas as well as promote sustainable development and reduce greenhouse gas emissions. Other projects are a water treatment project in Cambodia for a low-cost water treatment solution to improve access to clean water in rural and remote areas and a mobile payment solution to improve access to financial services and promote financial inclusion; a solar power project in Tanzania to improve access to electricity in rural and underserved areas, as well as promote sustainable development and reduce greenhouse gas emissions; a smart farming project in Thailand to improve agricultural productivity and reduce environmental impact, as well as promote the development of the local ICT industry; a waste management project in the Philippines for developing a waste-to-energy solution, reduce waste and promote sustainable development. These projects speak eloquently of assistance in achieving the SDGs and also demonstrate the potential for range of technologies for transfer and licensing support that could be accessed on specific need-based technology transfer. According to KIPO's 2021 annual report, KIPO granted 203,000 patents in 2021. As of December 2021, the total number of patents in force in Korea was over 2.2 million.

e) ***The State Intellectual Property Office of China (SIPO/CNIPA):*** According to WIPO's statistics database, CNIPA granted 424,000 patents in 2020. As of December 2021, the total number of patents in force in China was over 5.8 million.

Around 26.6 million technology patents with five IPOs in the

world can bring technology revolution in the least developed world if offered on humanitarian grounds. Pakistan can benefit from this technology reservoir through diplomatic efforts and by developing a technology diffusion culture in the country. Pakistan may need to change its decades-long demand for aid into trade and technology to benefit from this big technology reservoir of 26.6 million patents. While access to advanced technologies can play a critical role in promoting sustainable economic growth in Pakistan, NCST needs to ensure that the significant barriers *en route* such as financial resources required to acquire technologies, dearth of technical expertise, and inadequacy of infrastructure must be addressed. Some of the measures could be a cost-effective negotiated mechanism to share knowledge, expertise, and technology with the advanced countries, partnerships and collaborations for joint R&D, technology transfer, training and capacity building, and support for research and development e.g., in the areas such as renewable energy, healthcare, education, agriculture and water management, ICT etc. NCST may also explore accessing advanced technologies through international initiatives and programs e.g., the United Nations Technology Bank for the Least Developed Countries, which aims to help low-income countries to access and adopt advanced technologies, technical assistance for improving innovation and technology transfer capability as envisaged under the Global Innovation Index.

As for putting in place a conducive policy an institutional environment for NITS, technical assistance from multilateral institutions including UN system, World Bank etc., could be availed to build technical capacity and expertise, undertake policy reforms, address regulatory barriers and protect IPRs.

(ii) Bilateral Technology Transfer - The Type of Technologies and Fields

There is a huge potential for Pakistan to benefit from the advanced countries' technologies at a very low-cost or even no cost, through bilateral agreements to support attainment of the Sustainable Development Goals.

Some of the technologies which NCST through relevant technical ministries in their bilateral aid-agreements with advanced countries and their development assistance agencies should strive to avail for SDGs achievement include:

a) ***Goals 1 and 2:*** No Poverty and Zero Hunger- agricultural technologies: access to agricultural technologies to improve food security and promote climate-smart sustainable agriculture including high-efficiency irrigation systems, seed varieties, and crop management techniques to be adapted to local conditions for increased agricultural productivity.

b) ***Goal 3:*** Good Health and Well-being- affordable medical technologies: access to affordable medical technologies to improve healthcare outcomes and reduce the burden of disease e.g., low-cost medical devices, such as portable diagnostic tools or affordable prosthetics, which can be produced locally in Pakistan and healthcare software to improve healthcare outcomes and support the delivery of services;

c) ***Goal 7:*** Affordable and Clean Energy- renewable energy technologies: access to renewable energy technologies to promote sustainable development and reduce reliance on fossil fuels could be affected through bilateral arrangements including technologies such as solar panels, wind turbines, and energy storage systems, which can be used to provide access to electricity in remote and rural areas.

d) ***Goal 9:*** Industry, Innovation and Infrastructure- industrial technologies: accessing clean and green manufacturing processes, materials science, and robotics technologies that help the development of local industries and promote economic growth.

e) ***Goal 13:*** Climate Action- environmental technologies: access technologies e.g., for pollution control, waste management, and conservation and rational resource utilization to protect environmental integrity and eco-system.

The China South-South Cooperation Assistance Fund for Technology Transfer (CSAF): The program aims to help developing countries acquire and use advanced technologies to promote economic and

social development through funding and technical support for technology transfer. The program focuses on a range of sectors, including agriculture, health, energy, and environmental protection and is essentially based on the potential for promoting sustainable development and poverty reduction. Some examples of projects supported by the CSAF program include the development of solar-powered water pumps in rural areas of Africa, the establishment of a mobile health clinic in Central Asia, and the promotion of energy-efficient building technologies in Southeast Asia. Other examples are: training program on cassava processing technology in Zambia to achieve food security; solar power project in Sudan to provide electricity to remote rural communities for schools, health clinics, and other community facilities; agricultural technology transfer project in Ethiopia to improve agricultural productivity and food security in the country through the use of improved crop varieties, irrigation techniques, and post-harvest handling practices. Also included are: renewable energy project in Zimbabwe to promote the use of solar power in the country especially for schools and health clinics and to provide a reliable source of electricity; water supply project in Malawi to provide access to clean water in rural areas of the country including water storage tanks.

As Pakistan has very strong bilateral ties with China and in view of CPEC, NCST can really make use of CPEC Long Term Plan as a vehicle for transforming CPEC into a knowledge and technology corridor for technology transfer.

(iii) The Global Initiatives on Technology

There are several other IPOs and organizations that offer technology support, training and capacity development to developing countries which NCST should actively pursue. Some of these include:

a) ***World Intellectual Property Organization (WIPO):*** WIPO provides support for technology transfer and innovation through various programs, such as the Technology and Innovation Support Centers (TISC) and the WIPO GREEN platform. TISC provides access to patent information and training, while WIPO GREEN provides a marketplace for

green technologies and innovations.

b) ***Global Initiatives in Health Technologies:*** The global initiative on health technologies was launched by the World Health Organization in March 2008 to ensure member countries' access to appropriate health technologies. The specific aims of this initiative were to facilitate the effective utilization of resources and encouragement of pharmaceutical businesses and scientific communities to identify and adapt "innovative" technologies that can curb the incidence of diseases and especially have a significant impact on public health in developing countries. Some of the areas that Pakistan can benefit from include promoting healthier population, Joint United Nations Program on HIV/AIDS (UNAIDS), polio eradication, maternal and child health care and Global Fund to Fight Tuberculosis and Malaria, Gavi vaccine alliance etc.

c) ***Global Initiatives on Climate Change Technologies:*** Climate technologies and innovations have been on the forefront of global priority agenda to address the adverse impact of climate change on the planet earth. Pakistan is among the top ten worst affected countries in the world and as such there is an urgent need for the country to adopt and diffuse technologies and innovations to adapt to and mitigate the impact of climate change. The technologies globally available include: reducing greenhouse gas emissions (GHGs) through renewable energies –solar, wind hydropower; identifying the gravity of the problems -emissions hot spots with satellites and machine learning to track and analyze carbon dioxide (CO_2) emissions from power plants, factories, controlled burns, other human sources; spotting supply chain emissions through Artificial Intelligence (AI), recognizing energy leaks online, stopping further climate damage, developing lower-carbon energy sources and finding more efficient ways to use the energy e.g., solar-collecting fabric, waterpower generation using rain and steady flow of the ocean gulf stream; boosting energy efficiency to reduce reliance on fossil fuels e.g., carbon fiber, transparent wood, power-saving programming to reduce load time; mitigating building inefficiencies through sensors and analytics, use of carbon-based concrete, carbon-eating crops,

carbon-sequestering fertilizer etc. In addition, Kyoto Protocol promotes climate technology development and transfer based on five key technology themes:

- Technology needs and needs assessments;
- Technology information;
- Enabling environments for technology transfer;
- Capacity-building for technology transfer;
- Mechanisms for technology transfer.

The developing countries after identifying their technology needs, can access the above technology financing and capacity-building opportunities. The Global Environment Facility's strategic program on technology transfer also helps accelerate technology development and transfer to developing countries in the long term.

It may here be emphasized that the technology-transfer and licensing support involves negotiating licensing agreements and developing commercialization strategies that are mutually beneficial for both the technology owner and the recipient country. The process invariably involves the transfer of intellectual property rights, technical know-how, and access to manufacturing and distribution networks. As earlier averred NCST for a robust NITS must ensure that the necessary legal and regulatory regime is fully in place to access or import technology from abroad.

NCST should mandatorily submit a six-monthly progress report to PC for consideration. PC as an oversight body should ensure that the decisions taken by NCST related to NITS are implemented in letter and spirit by the Federal and Provincial governments and all concerned and that the required financial and HR resources are allocated without fail as per NITS execution plan.

Figure 22: Depicts the schematics for the Federal/ NITS

(iv) Area of Priority for Federal Government- Energy Sector

NCST, as a matter of top priority, during the course of NITS implementation, should pay special focus to the energy sector. Access to affordable energy is one of the major problems in Pakistan. According to the latest available data the potential electricity access in the country for 2022 was 94.92%, a 1.02% increase from 2019.[13] The lack of access in the rural areas and remotely located distant regions is one of the major problems. About 63% of Pakistanis live in rural areas, 37% of whom lack electricity. On top, the colossal costs of fossil-fuel, complexity of the distribution system, obsolete infrastructure and lack of large reserves of its own and foreign exchange reserves aggravate the situation. The irregular energy supply and load shedding is a perennial problem which afflicts both

the urban areas and the rural areas apart from the significant adverse impact on the industrial and the agriculture sectors. During the summer months from May-August 2023, just to illustrate, the electricity shortfall surged up to 7,000 megawatts with demand rising to 28,200 megawatts, while the power supply was 21,200 megawatts.[14] The power outage at some places is 18 hours a day duration while many rural or remote areas are still deprived of electricity and have not been electrified owing to lack of distribution system and transmission lines.

Ironically, the total installed power generation capacity in 2023 is reported 41,000 MW, of which 58.8% of energy comes from thermal (fossil fuels), 25.8% from hydro, 6.8% from renewable (wind, solar and biomass) and 8.6% from nuclear.[15] The demand as projected up to 2030 is growing on the average at a rate of 6.2 % annually while the capacity addition is increasing at 3.6% only.[16]

This lack of access to energy and the preponderant reliance on fossil fuels, apart from the jolt to industry and agriculture, have serious socio-economic implications, some of the major amongst them are:

- The ever-present problem of circular debt which is estimated at around Rs2.636 trillion at the end of Dec 2023;[17]
- Ever increasing electricity tariffs as a result of dependence on the import of fossil-fuel which is the major reason for the inflation in the country and rise in the incidence of poverty besides disproportionately increasing the cost of production and reducing Pakistan's competitiveness;
- Deprivation of the households from a basic necessity of life;
- Adverse impact on education- lack of continuous supply of electricity prevents the students from study and the educational institutions from functioning fully;
- Negative impact on the health sector: especially on the rural

populations from the perspective of fossil-fuel produced energy on local health; inability of health infrastructure to provide healthcare and use lifesaving medical equipment;

- Environmental degradation defying the achievement of SDGs and contributing to the worsening of the climate change impact.

It is thus important that renewable energy technology is adopted and diffused to increase the electricity generation, minimize the cost associated with electricity distribution and transmission infrastructure, eradicate power outages and make affordable electricity available to the people even in remote rural areas. The government has already established the Alternative Energy Development Board (AEDB) in 2002 which launched Alternative and Renewable Energy policy in 2019 to, inter alia, promote renewable energy and reduce carbon footprint and greenhouse gas emissions in the country. The Indicative Generation Capacity Expansion Plan (IGCEP) 2022-31, was launched by the National Transmission and Dispatch Company (NTDC), a laudable initiative, to add over 8,000MW from solar to the national grid over the next 10 years. AEDB intends to establish solar parks in the country to optimize the huge solar potential. The government also intends to eliminate taxes on solar and wind energy. These are appreciable initiatives but much more needs to be done to ensure constant access to electricity by developing and adapting affordable solar and wind technology projects sensitive to the variations and strength of the sunlight and winds.

The policy envisages an increase of share of green energy to 20% by 2025 and 30% by 2030. However, as of 2022, only a little more than 5% of renewable energy is produced in Pakistan which in itself speaks of the low priority and lack of commitment of the successive governments to make a shift from fossil-fuels to renewables (Sustainable Development Policy Institute –SDPI data). This slow- paced progress in implementing

alternative renewable energy (ARE) projects deludes the target and the set goals of 20% renewables in the energy mix by 2025 and 30% by 2030 thereby country's continued reliance on fossil fuel-based power projects.[18]

It may be emphasized that the cost–parity seems to have been already achieved between the traditional fuel driven power generation and ARE generation due to progressively decreasing prices for installation of the latter. There is already a huge potential for solar energy in Baluchistan to address the acute problem of electrification. The province holds the best solar irradiance value in the world with a possibility of saving 126,000 metric tons of CO2, if the entire population without electricity is covered by deployment of renewable energy. Similarly, there are wind corridors especially in the Southern Sindh, Western Baluchistan, northern hilly and mountainous areas of Khyber Pakhtunkhwa suitable for wind energy.

The Federal government, as a matter of utmost priority must use the NITS platform to unleash a collective effort involving academia and university research and expertise capabilities and private sector to develop integrated local- renewable energy solutions and technology. The assistance of donors should also be sought besides learning from and the successful experiences of many developing countries like Bangladesh and India for power generation and distribution at low-cost.

The government needs to do the following:

- create a conducive policy and regulatory environment including an attractive incentives structure for the private sector and local industry (for self- generation and indigenous capability for ARE) and integrate renewable energy as a component of development programs and projects (PDSP) in the country;
- should desist from the policy measures especially unjustifiable planned shift from net metering to gross metering to tap the full potential of solar energy which at present in 2024 is 1.41 gigawatt to 9.53 gigawatt by 2029;[19]

- develop dust-smog resilient solar technology to increase the power generation of solar panels (Quaid-e-Azam solar plant produces only 18.5% power against the 100MW installed capacity);

- institute a comprehensive capacity and "technical training for local renewable technology programs involving the universities and technical and vocational training authority (TAVTA) which will also create rural jobs and employment opportunities;

- develop cost-effective technological solutions for storage of surplus energy e.g., a flywheel system, a device that stores rotational energy;

- earmark adequate financial resources to ensure access to reliable flows of finance for ARE solutions;

- attract foreign direct investment (FDI) and local investment in the ARE sector which as of June 2021, cumulatively stood at US$4,796 million, of which US$786 million was in solar, US$3,752 million in wind, and US$258 million in bagasse while the expected investments for upcoming renewable energy power plants (solar, wind, and bagasse) over the next two years stand at US$866 million;[20]

- expedite the construction of hydel power dams e.g., $14 billion Diamer- Bhasha Dam which suffered since 1998 due to non-availability of the required funding and which at present, is in its preliminary construction phase and expected to be completed by 2028 to add 4,500MW of hydroelectric power to the system; Mohmand Dam which started in 2019 with an aim of producing 800MW of hydroelectric power due for completion in 2024; and fifth extension of Tarbela Dam installed capacity to increase to 6,298MW; and,

- launch information and communication programs especially for the rural households about the availability of ARE and encourage

communities to work with the local universities and industry for implementing ARE initiatives;

Indeed, access to affordable, reliable, sustainable and modern energy by all as envisaged under SDG 7 by 2030 could be significantly achieved through government and donor investment and aid, private sector active participation and the R&D effort of the university and research entities for technology transfer, development and innovation. This would be a game changer for rural communities all over.[5]

Succinctly, an accelerated shift towards green energy is an essential imperative for Pakistan in view of, inter alia, the unsustainable and exorbitantly mounting circular debt, high costs of per unit production and ensuring equitable and universal access to energy. The wind and solar-powered projects carry no fuel costs in power tariffs and significantly lower cost of power production compared to the pollution generation by the fuel-based power plants. The technology for solar power has become very cheap over the years. The cost of electricity from solar has come down by 87 %and the cost of battery storage by 85 %in the past ten years. According to a study by the Berlin-based Mercator Research Institute on Global Commons and Climate Change (2023), other fossil-free technologies, wind power etc., have also witnessed a sharp decline in prices.[21]

b) Provincial Level: At the provincial level, the respective Planning and Development Departments should take the lead in implementing Provincial Innovation and Technology Plans (PITP). The Chairman P&D should accord highest priority to implementing PITP. The Secretary P&DD with the assistance of Member (IT Services) should be designated to establish and supervise Knowledge Economy Resource Centre (KERC) to provide and arrange for technical advice and expertise to the stakeholders in the technology and innovation eco-system including the provincial departments, private sector and district governments in conjunction with a renowned think tank. PITP should be prepared in an inclusive by involving all the provincial departments, representatives of

the attached research organizations, Chairman Punjab Higher Commission, the representatives of public and private sector universities, the provincial Chamber of Commerce and Industry, research institutes and renowned scientists and think tanks. This execution plan- the provincial innovation and technology plan (PITP) - should complement and synergize with the National level plan to avoid duplication and wastage as well to create an enhanced impact and ensure accelerated implementation. PITP must adequately cater for, and, be sensitive and responsive to: (a) gender inequality; (b) regional disparity; and (c) rural- urban specific dimensions. Communication and advocacy must intrinsically permeate throughout all PITP's components.

P&DDs should ensure that every department earmarks sufficient resources for technology adoption, generation and innovation and at the same time the public sector development plan and the projects embodied therein have innovation and technology as an integral part. P&DDs should also issue guidelines and checklists for the establishment of a conducive policy and regulatory environment at the provincial level to facilitate NITS/PITP implementation and also incentivize a collaborative research based on industry needs comprising government, academia and private sector. They should also facilitate the carrying out of the roles and responsibilities of the quartet of government, private sector, university and higher education system and military as identified and spelled out in the preceding section. The provincial P&DDs and the KERC should also provide guidelines, toolkits and templates for District Innovation and Technology Plan (DITP) to be formulated at district level which should, inter alia, include:

- R&D Gradients – to identify and validate need and endowment driven new and innovative ideas that can drive growth in various sectors;

- R&D Challenges – to remove the impediments and pursue ideas that can solve problems;

- R&D Champions – to identify the lead person and develop a critical mass of R&D advocates to implement the ideas;

- R&D in P-P Mode – to develop R&D collaboration – public, private and NGOs to support the technology and innovation development;

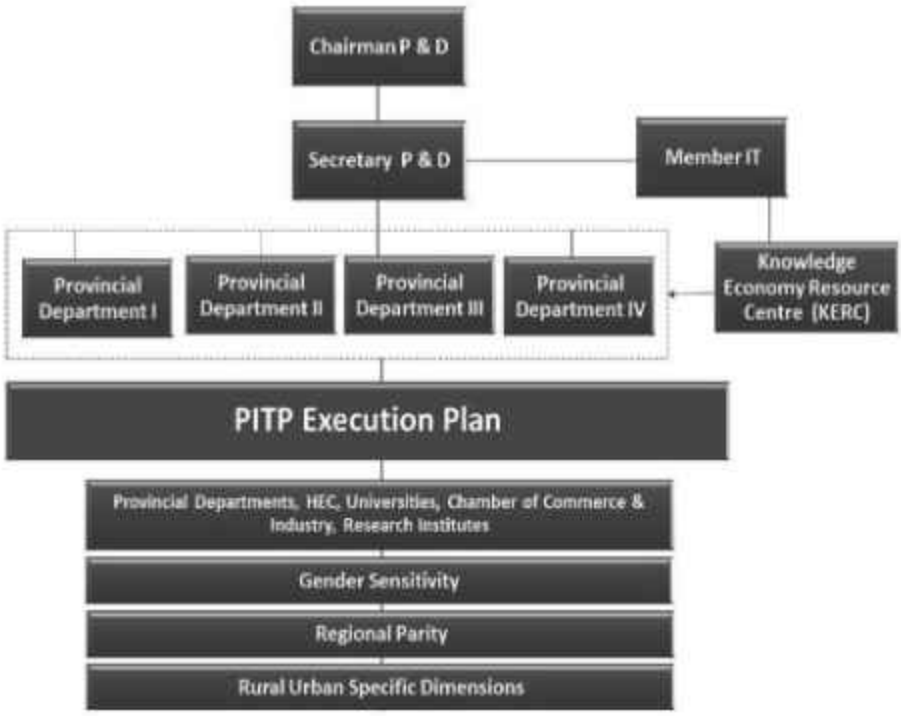
- R&D Smart Priority– to filter out priority projects viable in the short to medium terms having good ROI and payback;

- R&D Execution – to pilot and test ideas for validation and confirmation of new and innovative products and services that can be sustained;

- R&D Monitoring, Evaluation and Impact Assessment– to monitor, gauge and evaluate the impact of innovative projects and products on sustainable goals and competitive growth.

Figure 23 Captures the Contours of the Provincial Innovation and Technology Plan

Figure 23:



Areas of Priority: To start with, Provincial PITP should focus on application of technology and innovation in the agriculture and industrial sector.

(i) Agriculture Sector: Agriculture is the major sector with enormous potential to become engine of growth to achieve, *inter alia*, the national strategic objective of food security, alleviation of poverty and employment creation. It should be accorded priority focus especially for agri-commercialization, productivity gains and competitiveness and agro-industry. It could spur exports multiply to earn valuable foreign exchange and also serve to promote import substitution industry. Some of the various mechanisms and venues to acquire technology and benefit from technology transfer have been illustrated in the preceding section i.e., Technology Reservoir of the World, Bilateral Technology Transfer, Global Initiatives for Technology Transfer and, particularly, China's CSAF. The latter can be realized as low hanging fruit by harnessing the CPEC Long Term Plan and Chinese collaboration in the SEZs. This was pointed out by some of the interviewees as well. Innovation in agriculture can improve the quality and quantity of production and through value addition can fetch premium for producers in the international markets. With improved innovation and R&D, the agricultural sector can benefit from better agri-processing technologies and other inputs. Instituting a right STI policy framework can also help Pakistani manufacturing firms in the agricultural sector learn from China and develop indigenous technical capabilities to modify and build new agricultural machines through reverse engineering. This will also facilitate maximizing the agriculture potential and value addition through integration with regional supply chains and production networks.

(ii) Industrial Sector: Small and medium industries and enterprises are in a dire need of technological upgrades to gain competitiveness and become a part of global value chains and production networks. They hold enormous potential for STI interventions. As discussed in the

econometric model subsection of this report, interventions for high-tech industries are not suited for the stage of economic development through which Pakistan is currently passing. Therefore, firms in the light and medium-tech industrial sectors of food processing, auto parts manufacturing, domestic appliances etc., can be treated as the major sectors for innovation related interventions. Incremental innovation needs to be encouraged. The government must make sure that the businesses especially the exporters are given the appropriate incentives, and these are implemented in letter and spirit with minimum bureaucratic delays and red tape. Input and advice from the business community for the policies and programmatic interventions must be taken as majority of the enterprises in Pakistan feel that they are not taken on board for formulating various policies, plans and programs which can affect them directly or indirectly.

c) District Level: The implementation of NITS at the district level is *sine qua non* for its success and reaping immediate dividends and traversing at an accelerated pace the journey towards transformation to technology-innovation led knowledge economy. It will have an enhanced and visible impact on increasing productivity, achieving competitiveness and creating employment opportunities. The importance of NITS concurrent implementation at the district level through District Innovation and Technology Plan (DITP) is essentially imperative to addressing the pervasively prevalent socio-economic problems and state of multi-dimensional poverty especially in many rural districts of Pakistan.

Poverty Alleviation: According to PIDE report (2021), incidence of poverty has declined in Pakistan from 61.6% in 1998-99 to 21.5% in 2018-19. During the period, the urban areas witnessed poverty reduction from 47.4% to 10.7% while in rural areas the decline was from 67.5% to 27.6%.[22] At the district level, however, the World Bank Report of 2017 which presents the latest data in case of Punjab - the most populous area of the country-, the poverty rate in rural areas is twice than in urban areas with four out of five of Punjab's poor living in the rural areas. The

province is also the most economically unequal province of the country with Rajanpur as the poorest district of the province in 2015-16 in terms of incidence of poverty. In total, 10 of the 36 districts of Punjab witnessed an increase in the poverty headcount ratio from 2012-13 to 2014-15: 15 out of the 36 districts of Punjab saw an increase in the intensity of poverty, D.G. Khan the highest at 9.6% and Kasur, Chakwal and Sahiwal with 0.8% respectively[23] which is palpably indicative of a negligible performance in alleviating the multi-dimensional poverty of the masses, let alone with technology and innovation, moving towards knowledge based economy and global competitiveness of which plethora of opportunities exist. The poverty situation has since worsened especially during the two recent successive alliance governments. As of 2023, the intensity of multi-dimensional poverty among the people at national level stood at 51.7 %.[24] While the development priorities and resource allocation are guided by Annual Development Programs, Punjab Growth Strategy 2023 and Punjab Spatial Strategy 2047, there is lack of urgency to develop the districts and transform their development paradigm to innovation and technological advancement.

This calls for a serious effort to promote technological innovation at the district level in Pakistan by implementing District Innovation & Technology Plan (DITP) vertically linked to, synergized with and developed on the same contextual theme as the provincial and national NITS. The provincial government should not only provide financial, regulatory and programmatic support to the districts but also build the capacity through issuing accredited certifications of technology and e-commerce related disciplines to the citizens. Along with it, the need to provide standardization of the work practices and certifications will also be met. The districts should also be able to avail the necessary technological, experiential, community and institutional linkages, along with access to the Knowledge Economy Resource Centre (KERC) at the provincial headquarters located in P&DDS. KERC would help the districts understand first- hand the development strategy designed for NITS, PITP and DITP and would also be responsible for building the public –private

partnerships (PPP).

The Deputy Commissioners should take the leadership role and use the respective district development committees as the pivot for implementing DITP. More specifically:

- A District Innovation and Technology System based on the local production system should be formulated in the light of PITP and NITS involving local industry and chamber, university and technical education system and government departments;
- All the major sectors and departments should identify the priority areas for technological and innovation interventions categorizing them as (a) the ones entailing new technological solutions based on the local needs for productivity enhancement and competitiveness; (b) requiring technology transfer and diffusion based on the local successful applications; and (c) compendium for technology imports.
- The fragmented development projects at district level should be transformed into a unified whole in line with DITP with technology and innovation as integral parts of the district development plan;
- DITP should ensure decent work opportunities for all genders according to the principles of the UN Global Compact,[25] and sustainable social and economic development that is enshrined in the sustainable development goals (SDGs) i.e. 1,5,8,9 respectively.[26]
- Special economic and technological hubs should be identified in the DITP based on local production systems and needs which should also provide means for access to finance, technical advice and technology, training and expertise development and access to domestic and external markets. CPEC connectivity provides an excellent opportunity to use as Knowledge and Technology Corridor.

- DITP should also provide a platform and portal to assist the local industry become part of the supply and value chain - national, regional and global.

The provincial government should be a direct stakeholder in the implementation process. The policy and regulatory support would be provided by the provincial government. The districts should also derive the facilitation and implementation support directly from them as is the case for other developmental projects.

Briefly the implementation framework and intervention model for various tiers of the system are portrayed by the following figure

Figure 24: Implementation Framework and Implementation Model

34. Financing the National Innovation System of Pakistan

Before, describing the financial instrument and mechanism, it may be appropriate to briefly dwell on the dilemma and vicious circle of financing innovation and technology development. The country has no fiscal space to allocate hefty funds for R&D. The private industry operates at relatively a very thin margin and earns meagre profits to

finance EDF and R&D and invest in new technology projects. Corruption and complexity of regulatory framework and procedures add to the business costs and impact the profits margin. The input costs e.g., electricity, gas etc., are very high, making it difficult to compete in the international market. This discourages the industry from making risky investments in R&D and innovative projects for future growth and market demands and propels industry to confine it to secured business options like trading and non-value- added production. This dilemma keeps the industry in traditional production with very low incremental innovation and investment in new technologies.

On the contrary, countries like Taiwan, Singapore, China and South Korea have emancipated them from this vicious circle of financing innovations and institutionalized a robust financial mechanism to invest in new technologies. Pakistan needs to learn how these countries were able to break the vicious circle and grow from less developed to emerging markets of the 21st Century.

As for the university-industry nexus, the cumbersome procedures, political instability and consequent policies' inconsistency, the upfront associated high costs and poor trade diplomacy hinder the R&D collaborations and partnerships. There is practically little appetite in the industry to benefit from local scientific works, expertise and technical capacity or to interact with academia, offer research scholarships and fund lab technologies for commercialization. Thus, the state and industry both are unable to finance research.

As is evident from above, the government has to play the predominant role to improve a country's absorptive capacity in order to promote technology development. The country-specific configuration of interacting institutions and the associated financing mechanism is vital for promoting innovation and technological capabilities. Innovation policies must therefore be linked to and anchored in the overarching knowledge economy goals and fully supported by specific programs and financial instruments for adequate investment in R&D and for promoting innovation

and technology development.

A combined or dualistic policy of direct government support and FDI, for a country like Pakistan, seems to be the most viable option for sustainable R&D investment and innovation and technology development in the country. This model is already partially in vogue in the country. The right political will and the professional management of resource kitty directed to technology and innovation led growth, as experienced by the successes of recently emerging markets, could muster adequate investment and financing to bring or import already available technologies for successful adoption and diffusion. This will ultimately culminate in increase in productivity and competitiveness, exports and GDP growth. The industry-given fund like Export Development Fund (EDF) is a case in point towards technology import and adoption.

Pakistan thus needs to initiate industry related research, innovation and technology development funding which will stimulate demand for technology, university-industry nexus, returns on R&D investment and create surplus funding. This will create a virtuous cycle of generating surplus funding to be reinvested in technology creation followed by cutting-edge research funding.

R&D and Innovation Financing - the Developed Countries' Experience: The countries with developed R&D systems like the USA, China, Israel, South Korea, Taiwan, Singapore, Germany and Japan offer multiple streams of funding in basic and applied R&D. These funding and grants are contributed by the public and private sectors and international institutions. There are generally six major areas of R&D finance: (i) public sector funding for basic research for academia; (ii) public sector funding for technology for industry; (iii) public sector funding to cover the risk in priority technology areas for industry; (iv) private sector investment in technology development for industry; (v) private sector fund in technology scale-up for industry; and (vi) international and institutional funding for R&D.

The Governments fund the high-risk and uncertain areas of R&D while the private sector invests in quickly convertible and adoptable solutions, low-risk and high-reward areas. The industry also invests in the transformation and conversion of research lab results and solutions into new products and innovative technologies.

The Table 7 shows the R&D expenditure by major countries including the developed and emerging economies compared to Pakistan in 2020 which makes it abundantly clear how low priority Pakistan attaches to technological development.

Table 7: R&D Expenditure by Countries in 2020

Sr.	Countries	Expenditures on R&D (Billions of US$, PPP)	% Of GDP PPP	Expenditures on R&D per Capita (US$ PPP)
1	United States	612.7	3.5	1,866
2	China	514.8	2.4	368
3	Japan	172.6	3.3	1,375
4	India	158.7	1.3	120
5	Germany	131.9	3.1	1,586
6	South Korea	100.1	4.8	1,935
7	Turkey	24.8	1.1	297
8	Malaysia	10.6	1.3	344
9	Singapore	10	2.2	1,832
10	Pakistan	2.4	0.3	13

Source: Main Science and Technology Indicators, Volume 2022 Issue 2; OECD

The above Table palpably indicates that in terms of overall volumes of expenditures, USA spent US$612.7 billion followed by China US$514.8 billion, Japan US$172.6 billion, India US$158.7 billion and so on while Pakistan spent only US$2.4 billion on R&D. As for the GDP ratio, South Korea ranks number one with 4.8% followed by USA 3.5%, Japan 3.3%, Germany 3.1% and China 2.4%. Pakistan with 0.3% GDP ratio presents a very bleak picture.

The data on per capita R&D investment in Pakistan is also very low

just US$ 13 as compared to India at US$120, Turkey at US$297, Malaysia at US$344 and South Korea at around US$2000. It may be reiterated that South Korea was behind Pakistan back in the 1960s and now spends US$ 100 billion on R&D which is almost forty-five times higher than the total export of Pakistan.

The fact, as established by the successful experience of the developing and emerging economies, is that higher R&D investment and expenditures invariably lead to increase in exports and improvement in the Global Competitiveness Index score (GCI). Table 8 clearly shows the direct relationship of investment in R&D with the overall exports and GCI of China, Germany, India, Japan, Korea Rep, Malaysia, Pakistan, Singapore, Turkey and USA.

Table 8: R&D Investment and Development

Country Name	Export USD Billion (2019)	R&D) % of GDP) Year Ave (1996-2019)	R&D (% of GDP) 2019	GCI 2019
China	2,628.94	1.5	2.24	28
Germany	1,832.87	2.6	3.17	7
India	529.24	0.7	0.66	68
Japan	893.78	3.1	3.22	6
Korea, Rep.	648.61	3.1	4.63	13
Malaysia	238.38	0.9	1.04*	27
Pakistan	30.13	0.3	0.17	110
Singapore	661.71	2.0	1.89	1
Turkey	251.69	0.7	1.32	61
United States	2,538.45	2.7	3.17	2

Source: The Global Competitiveness Report 2019; Klaus Schwab, World Economic Forum and World Bank Indicators; *2018 latest available

Pakistan in view of low R&D investment and financing of new technologies (only an average of 0.3 % for more than a decade, further reduced to 0.16 % in 2022 as per the latest figures available) continues to perform poorly both in terms of its ability to increase exports and to

improve its competitiveness in the global market. Its GCI ranking stood as low as 110 out of 141 countries in 2019.[27]

The success of the higher export performing countries suggests that these countries more or less followed a pent-angular approach comprising enabling environment for FDI with technology transfer; enabling local industry to adopt foreign technologies; focus on the export increase and import substitution; establishment of quality higher learning institutions for competent human resource; and access to multiple streams of finance for innovation and R&D.

Pakistan needs to learn from the technology and innovation driven pathways and development trajectories followed by these successful countries to catch up and grow. The case of structural development of NIS of the emerging economies of Malaysia and Thailand is in particular relevant. In both these countries, the government has taken the leadership to provide strategic direction and support the process of transforming R&D results to commercialization through institutional and financial arrangements. The major thrust of expansion of their economies is on knowledge-intensive activities and incentivizing the multinationals to drive technological development and innovative activities.[28] For Pakistan to embark on the innovation and technology financing system for its NITS, therefore, a drastic departure from status quo-R&D shy model is required. This would involve a combination on the one hand of political governments' will to create a conducive environment for multinationals for technology import and diffusion and on the other strengthening of responsive social and entrepreneurial institutions for local specific out of the box solutions. The country needs to nurture technology and innovation receptive culture all across including government, businesses, academia and universities.

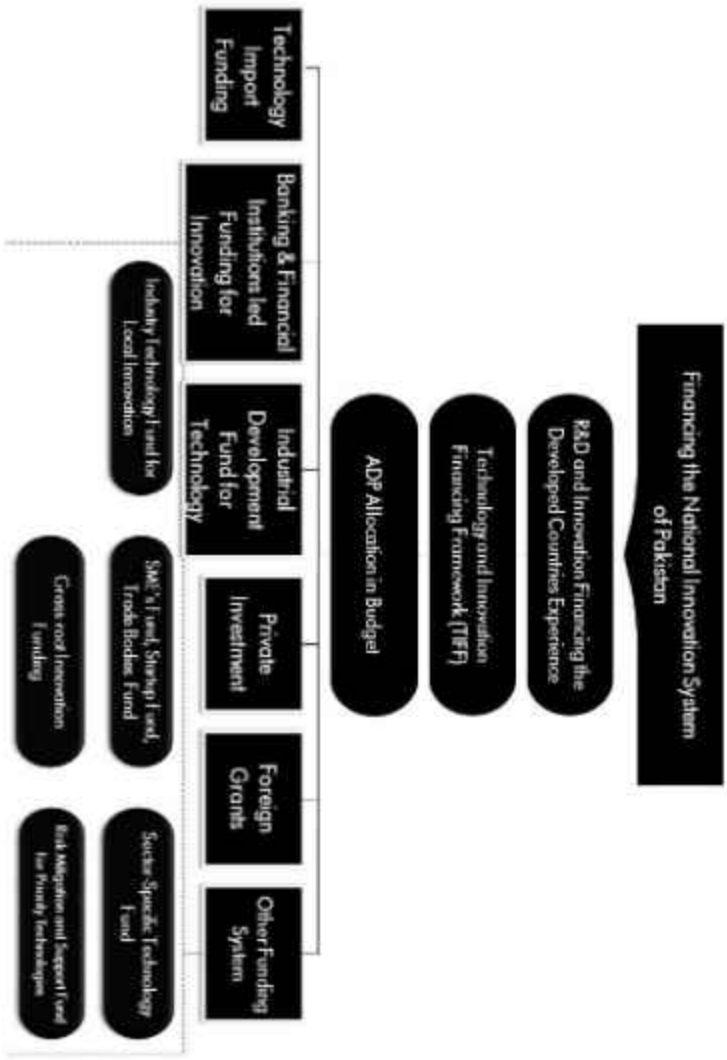
Based on the experience of successful countries; available models and frameworks globally and local context specificity, the following financing mechanism and innovative growth model for NITS is recommended which besides spurring innovation-technology led

development will also help leapfrog growth especially in the export sector. This model envisages mobilizing all possible sources and venues of accessing technology and finance e.g., Global Technology Reservoir, Bilateral Technology Transfer, Global Initiatives on Technology etc., which the government and NCST should integrate in the Technology and Innovation Financing Framework

(i) Technology and Innovation Financing Framework (TIFF)

The Planning Commission along with NCST through an inclusive process should develop a robust resource mobilization strategy i.e., Technology and Innovation Financing Framework (TIFF) to ensure sustainable financing of NITS and technology and innovation led growth. TIFF envisages five distinct but complementary components which together provide a composite and holistic framework for financing NITS and its sustainability. These are: technology import funding; foreign grants and technical assistance; banking and financial institutions' led innovation; private sector investment and other funding streams as depicted by the following figure 25.

Figure 25: Technology and Innovation Financing Framework (TIFF)



a) Technology Import Funding

This involves a major commitment of the Planning Commission and NCST to divert a large chunk of already available, though, meagre resources towards prioritized technology imports with the assistance of international and donor development partners. This need-based technology import will lead to both upgrading the existing industry as well as the

establishment of new industries. The resultant competitiveness, productivity gains and integration with the global value chain and ultimately with global production networks will lead to a significant increase in GDP and growth in export besides creating employment opportunities, generating economic activities and creating wealth and revenues for everyone e.g., private sector, government etc. The surplus wealth will allow the private sector and government to localize and indigenize imported technologies, invest in R&D and sustain a virtuous cycle of regularly financing NITS. A technology-driven diplomacy, as stated earlier, could play a pivotal role in attracting foreign technologies to Pakistan.

b) Industrial Development Fund for Technology

Pakistan collects significant amounts of resources under the Industrial Development Fund to which the pharmaceutical industry, the telecom industry and others contribute a pre-determined share of their revenues. Similarly, the Export Development Fund is also collected from industry. A major part of these funds should be devoted and utilized for technology imports to increase exports and substitute imports. This will substantially reduce the dependence of R&D allocations on the national budgets. The industry, through additional incentives, should increase its contribution to these funds which should be back-invested in industrial growth, innovation and technology generation and diffusion.

c) Foreign Grants

Foreign research grants for R&D purposes constitute a major financing source especially for developing countries. In order to, however, access these grants, it is essential to equip and train the scientists, members of the academia and the relevant government functionaries with the know-how and capacity to write feasible research proposals and projects. The HEC has already launched a flagship program "National Research Program for Universities" (NRPU) for funding high-quality and promising scientific research projects which have strategic relevance and impact to the local industry and society. Pakistan has spent almost Rs. 100 billion on the

NRPU projects that have developed significant local capacity to bid for international research grants and funding. The government and the universities should support the scientists and help them identify and access huge amount of international and foreign grants for basic research of which Pakistan's share at present is minimal. According to estimates (2018), Pakistan produced around 45,561 PhDs in the last 10 years and around 10,000 foreign- qualified PhDs with exposure to the global research world. These scientists can be encouraged to write proposals and bring foreign money into Pakistan.

d) Banking and Financial Institutions' led Funding for Innovation

The banking sector has played a very significant role in innovation, industrialization and economic growth. The emergence of banking in the medieval period caused the birth of industrialization in Europe. Similarly, the Bank of China played an important role by financing innovative projects in China. The technology import in China is actually led by the banking sector. Pakistan should, therefore, create a financial stream obligating the banking and financial sector to design and offer specific financial products geared to technology import by the industry. A financial product of the banks and financial institutions guaranteed by the government could encourage the industry to upgrade their plants and production processes through joint ventures with foreign technology players. Low-cost finance specially designed for new technologies for import substitution and export increase should also be provided by the banking and financial sector to promote innovation and technological advancement.

e) Private Investment

The enabling ecosystem and environment comprising policies, regulatory frameworks and incentives regime should be developed by the government to attract local investment and FDI in technology-driven value-added industries and joint ventures to bring new technologies to the country. Incentives to startups aiming at new technologies and innovations should be a dominant part of this regime.

For this purpose, Venture capital (VC) is, inter alia, the most widely instituted financing mechanism to stimulate research and development activities including promotion of basic scientific research for technology development and its commercialization which links research to marketable innovations.[29] In Pakistan, however, VC is still in the infancy stage. The government should take the lead in initiating the process by setting up a robust VC Fund and, at the same time, introduce policies and incentives regime to attract domestic and international VC firms with the grant of status of an industry to Pakistan.

f) Other Funding Streams

Pakistan is yet unable to offer diversity in its funding streams and is highly concentrated on meagre public sector funds for academic research. Recently a good effort of a technology fund was launched by HEC for the universities and academic institutions of higher learning but the country needs to explore a range of other funding streams to stimulate R&D programs, especially for the industry and create a technology-driven competitive markets. The range of options includes:

- Industrial Technology Fund for Local Innovation: for organizations, entrepreneurs, technicians and scientists endeavoring to develop local technology having the potential for import substitution or export enhancement;
- Industrial Technology Fund for Tech Import: for businesses desirous of or need to be encouraged through funding to upgrade the existing plans or install new ones based on imported new and efficient technologies;
- Risk Mitigation and Support Fund for Priority Technologies: for high-risk and high-priority technologies like renewable energy, space, healthcare and mining;
- Grass-root Innovation Funding: especially for the district and local levels to be administered by the Deputy Commissioner within the

ambit of DITP to solve local industry problems and increase productivity and competitiveness of the district specific and endowment-based sectors;

- Sector-Specific Technology Fund: to be focused on sector specific identified priorities to enhance their competitiveness in the global market and enable them to integrate with regional and global value chains as well as to encourage both import substitution and export enhancement;

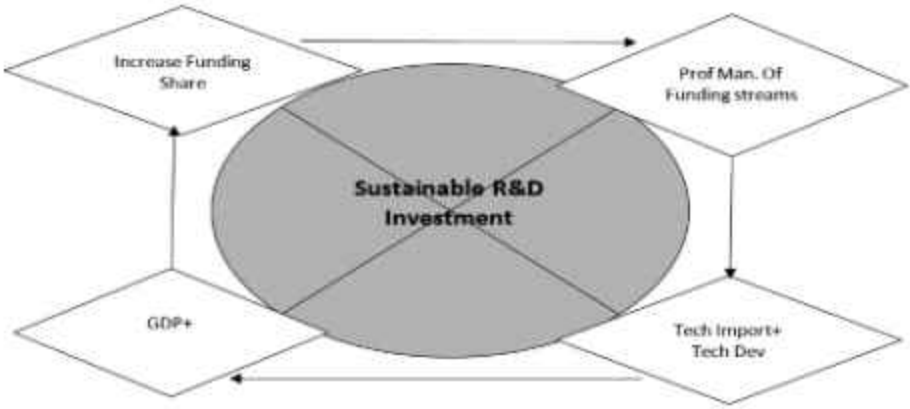
- SMEs Fund: already allocated and earmarked by the State Bank be expanded to help SMEs upgrade their systems and processes and increase their business base with a special focus on quality, productivity innovation and technology diffusion in the SME sector;

- Startup Fund: for local entrepreneurs, technicians and youth; and

- Trade Bodies Funding: to support new technologies and startups by the trade bodies and chambers in their respective areas and fields to, inter alia, promote a culture of private investment for innovation and innovation-led growth.

It may be emphasized that TIFF offers a robust and reliable framework for NITS's financial sustainability and provides with the critical mass of resources for innovation and technological development. What is required as has been repeatedly reiterated is the strong political will and professional management of different streams of funds to fuel innovation-led growth, create wealth, institute a virtuous cycle of R&D and increase exports and improve general well-being of the people. The following figure 26 captures the functioning of the R&D virtuous cycle:

Figure 26: Sustainable R & D Investment



The important features of the above model are: i) the professional management of the funding from all streams including industry given funds without misuse; ii) funding given to research institutions-industry for the latter to quickly convert funding into business and economic growth; iii) funding given for technology imports and/or local development of viable technologies and iv) industry willingly and sincerely contribute back to the fund and the universities- research institutions access funds for technology development. The professional management of the funds will increase the trust and credibility of TIFF, for which, the Planning Commission and NCST along with the provincial and district outfits have to institute effective and transparent mechanism and dashboards to monitor pre-determined Key Performance Indicators (KPIs) and targets. The system will also solve the long-standing problem of Pakistan in terms of giving impetus to industry demand for technology and innovation and strengthening government-industry-universities-academia nexus. The government needs to establish a precedent in raising and allocating non-fungible funds by the respective ministries and departments for R&D in their ADPs and also make use of technology to enhance departmental efficiency and service delivery.

35. Conclusion

The rapidly evolving world political and economic order

characterized by globalization mingled with regionalization and rapid pace of technological development, has drastically challenged the national economies, in particular, their ability to remain relevant, responsive and competitive in their quest for sustainable and equitable development. The interaction and relationship between the government, private sector, citizens and social institutions (especially the knowledge generating system) have assumed unprecedented importance as well as uncertainty given the intensity of pace of competition, emerging trends, the dictates of geo-economics and the consequent constant pressures on public policy, knowledge, innovation and technology generation and the wealth creation strategy of the private sector. In the midst of this nebulousness and lack of certainty about the future, the singular facet which remains undeniably certain is the pivotal role of science, technology and innovation (STI) in shaping and designing the national as well as global political and economic order. STI will also determine the configuration of social and economic interaction and relationships between the quartet of government, private sector, the learning and knowledge system and the citizens on almost all issues – including all dimensions of human security, international affairs and institutions, the environment, private sector business strategy, regional development, the major thrust of research and scholarship, intellectual property, ethics, law etc.[30]

It is also recognized all over the world that technological change and innovation invariably derive from the blend of practical knowledge, creativity and disciplined theoretical discourse. Indeed, innovation and technology development are the result of a complex set of relationships among various actors and players which include enterprises, universities and government research institutes. The focus in the process is not only on traditional technology development framework based on primarily inputs e.g., expenditures in research and development and outputs e.g., patents for new technologies, but also on the dynamics and network of interactions among the actors involved in technology and knowledge product development. The innovation performance is not contingent solely on the characteristics and abilities of the individual actors and institutions but

very much on the different kinds of relations between them and the ways they interact with each other including with the government sector. The character as well as the change of the economic patterns of interaction are central parts of the system of innovation and technology development especially the economy's emerging institutional set-up and the pattern of specialization or industrial structure. It is only through understanding of the technology and innovation system in its entirety that the policy and decision-makers could formulate the policy and strategic approaches for accelerating the pace of transformation to the knowledge based economy. Institutional linkages and human resource flows between the government, private sector and universities, establishment of industrial clusters and innovative firm-business culture constitute an integral part of the process.

This, a priori, entails the establishment and implementation of all-encompassing National Innovation and Technology System covering all tiers across all sectors to muster and channel a collective effort of the troika of government, private sector and universities towards innovation and technology development. NITS will and generate and induce a systemic approach to nurturing a wider societal culture and receptivity of creativity, innovation and technological development. NITS also creates the platform and environment to allow smooth flow of technology and knowledge (both tacit and codified information among people, enterprises and institutions) and vertical and horizontal connectivity, collaboration, networking among the actors, enterprises, universities and research institutions for innovation and technology development and diffusion. It augments their capacity to (i) identify and develop new technologies and innovations through joint research, co-patenting, co-publications and (ii) improve industries' adoption rates for new technologies and upgradation of the technical know-how and expertise of their personnel for productivity gains and competitiveness.

It is imperative for Pakistan, as such, to establish a fully resourced and functional NITS to embark on innovation-led growth and shift its trading and traditional economy into a value-added production economy

and ultimately knowledge economy. A condition precedent, however, as assiduously reiterated, is the political commitment and a proactive role of government to establish a conducive and stable policy environment and make significant R&D investments to help industry benefit from new and innovative ideas and technologies generated by academia. This will drive the process of transformation of these technologies into products and services through adoption and diffusion, create an immense amount of new value, develop HR expertise for productivity enhancement and help achieve global competitiveness. The country with USD 25 billion in exports will thus catch up with the emerging economies which have recently reached USD 300 billion exports based on their progressive and determined shift to knowledge economy and technology led growth. The leapfrog progress is a big challenge but not an impossible one as fast growth has already been achieved by many countries in recent history. Pakistan with an R&D investment of USD 2.4 billion cannot compete with countries investing USD 100 billion in R&D and needs to diversify and expand its R&D investment portfolio, involve other stakeholders to partner in R&D investment, offer multiple streams of technology funds and develop a sustainable model of R&D investment.

To start with, the country should engage in a two-pronged approach i.e., focus on R&D devoted to technology import and assimilation for wealth creation and export expansion and import substitution; and, the diversion of the surplus of created wealth to R&D investment to support cutting- edge research and development for innovation and new technology creation. This will involve, in the first instance, revamping the education system, focusing on creating a conducive environment for attracting FDI combined with technology import, incentivizing industry for exports, revitalizing and financing R&D institutions to work on the indigenization of imported technology and its absorption and adoption by local industry for wealth creation. The country, as a consequence, will be able to make use of the technology for creating indigenous scientific and innovation capacity towards shaping the knowledge economy. Once the contours of a knowledge economy are

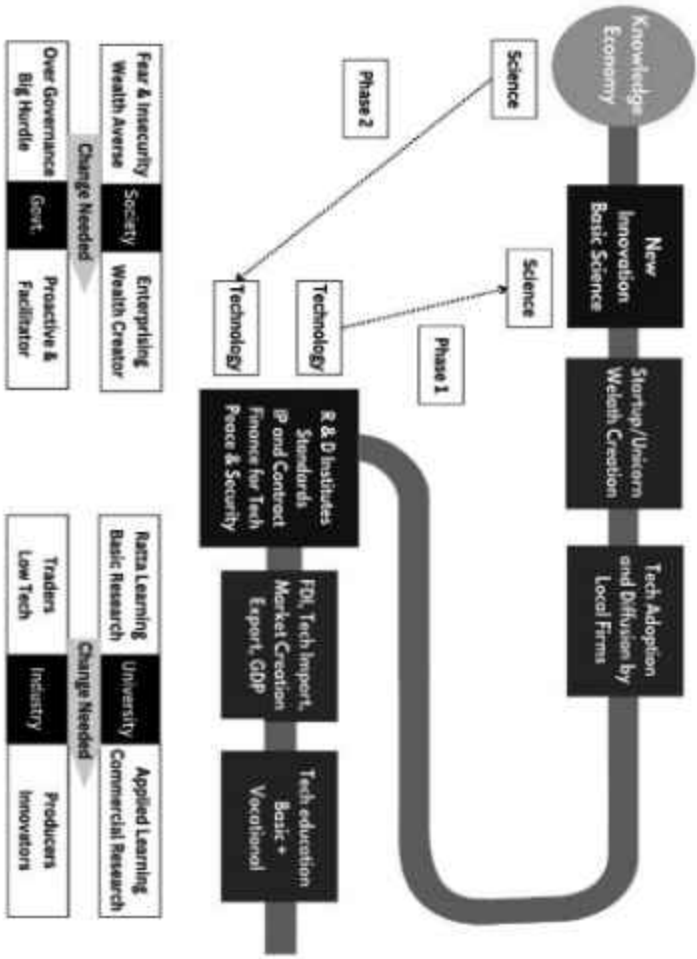
established, the country is ripe for the second phase of developing innovations and technologies as illustrated in Figure 27.

This transition by no means follows a 'linear' path from basic research to applied research and further to the development and implementation of new processes and new products. Instead, it is characterized by complicated feedback mechanisms and interactive relations involving science, technology, learning, production, policy, and demand. The dynamism of the real world may warrant, during the transition phase from relatively stable "status quo" systems to more transitory and unstable 'hybrid' forms before achieving maturity and stability. The roles of all the major actors and institutions are very crucial to appreciate, understand and share the 'insight' and "commitment" that the creation as well as the diffusion and utilization of knowledge, innovation and technology, whether planned or unintended by-products of the economic activity, are important for competitiveness and sustainable economic growth.

It is also important to address the apprehensions, some of which may be genuine, that while technological advancement and innovations lead to productivity gains, wealth creation and welfare and distributive justice, the associated changes in production and consumption patterns may render the old skills obsolete and destroy old jobs. However, they invariably create a plethora of opportunities for new employment and hence the role of the education system and technical and vocational institutions to rapidly adjust and produce right kind of skills-mix and expertise demanded by the changing labor market.

A concerted, unified and earnest effort by government, society, industry and universities as described in the "Charter of Innovation" is sine qua non for this to happen. NITS provides the framework and the platform to successfully achieve this ideal.

Figure 27: S & T Road Map for Pakistan



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Postscript: The National Innovation System and Industrial and Technological Advancements

Industrial development is typically driven by transformative technological advances, which lead to fundamental changes in how the industry functions. These changes have economic, societal and environmental consequences some of which are intended and desirable while others unintended and undesirable. The First Industrial Revolution of early 18th century was marked by a transition from an agrarian economy to a manufacturing economy where production methods no longer involved solely manual or animal labor but shifted to machines powered by steam or water. The increased production and efficiency, lower prices, availability of a variety of goods, improved wages etc., were the salient gains. The world, however, underwent seismic societal changes leading to rapid urbanization and migration of people from rural areas to urban areas with concomitant impact on lifestyle and well-being of the people. This impact was manifested in the pathetic and dangerous living conditions of the workers, malnutrition and food deficiency, rampant incidence of diseases like cholera, tuberculosis and typhoid, child labor, discrimination against women etc. The first industrial revolution IR1 albeit brought about many technological advancements and inventions which created a plethora of job opportunities and demand for new skills, inspired further innovation, spurred competition among industries, and improved the process of thinking and manufacturing.[1] The second industrial revolution IR2 marked, among others, by electricity introduction, from the late 19th to early 20th centuries further changed the world and the pace of life in many ways. The cities sprawled; industrialization especially steel, chemical and power generation expanded and transformed into modern production lines; distance shortened considerably as the means of communication and transportation of people and goods developed extraordinarily. The exchange of ideas, knowledge and information across and within the countries evolved remarkably and above all materialism and consumerism, with high productivity and economic growth, emerged as the defining societal value and ethos to impact people's lives and life style.

"It was a tremendous transformation of people's lives," remarked Joshua B. Freeman professor of history at Queens College and author of Behemoth: The Making of the Factory and the Modern World.

The third industrial revolution IR3, which began in 1950s, ushered in the computer, electronic and digital age and use of communication technologies in the production process, leading to automated production. Nano, bio, and IT technologies and innovations such as the internet, social media, mobile phones and apps, cloud computing, big data, e-commerce, etc., 3D printing, artificial intelligence, robotics, etc., were the major advancements and drivers of IR3 which also brought about a more distributive spread of the wealth in the world. With almost 10 times increase in the world wealth, every part of the globe benefited as thousands of businesses, services, and enterprises were established and developed offering millions of jobs. The standard of living and life expectancy increased globally. The latest inventions, e.g., Smart dust, quantum computing, man-computer interface, autonomous vehicles etc., have impacted every sector of society and made the life more comfortable and convenient. It has indeed led to the explosion of knowledge in ICT, transportation, advanced manufacturing, distribution, consumption, medical and health, education, agriculture, construction, defense, business, economic activities, administration, etc. However, IR3 also brought in its wake some negative impacts, such as air pollution, biodiversity reduction, water pollution, habitat destruction, greenhouse gas emissions, global warming and climate change.[2] The huge pressure on the global economy and the phenomenon of budget deficits have proliferated besides replacing many workers with machines.

In recent past decades, the world has entered in and adopted the fourth industrial revolution IR4, originated in Germany around 2011 as high-tech strategy which advanced the concept of Cyber Physical Systems (CPS) - a technological innovation that achieves intelligent control using embedded networked systems- into Cyber Physical Production Systems (CPPS) with Smart Factory as one of the key associated initiatives of

Industry. Built on IR3, the digital revolution, it is characterized by a "fusion of technologies that is blurring the lines between the physical, digital, and biological spheres".[3] Its scale, scope and complexity have a transformative effect in altering the work methods and culture, the lifestyle and the human relations. The nine key enabling technologies of IR4 are: big data and analytics, Autonomous robots, Simulation, Horizontal and Vertical System Integration, Industrial Internet of Things, Cybersecurity, Cloud, Additive Manufacturing, and Augmented Reality. IR4 evolution has been exponential rather than linear which has disrupted almost every industry and the entire systems of production, management, and governance. Global economic growth, income levels and improvement in the quality of life of people around the world are intended to be achieved due to long-term efficiency and productivity gains, reduction in business, trading, transportation and communication costs. IR4 could, however, yield greater inequality as automation substitutes and displaces the workers with machines. IT may also dehumanize and "robotize" humanity and deprive mankind of "heart and soul" but at the same time, unfolds a plethora of opportunities for expression of human creativity, empathy and leadership to elevate the collective and moral consciousness based on a shared sense of destiny of mankind. To accomplish this, there is definitely a need to develop a comprehensive and global consensus to use technology in reshaping the political, economic, social, cultural, and environmental streams of human life.

At the ten-year mark of the introduction of IR4, the European Commission announced IR5 "Towards a Sustainable, Human-centric, and Resilient European Industry" which generally refers to a shift of the focus from individual technologies to a systemic approach and future state of the industry where advanced technologies such as artificial intelligence, automation, quantum computing, generative AI, and the Internet of Things; are designed and employed to augment and amplify human creativity and innovation.[4] It postulates a powerful role of the industry to achieve societal goals beyond jobs and growth and ensures larger and resilient human prosperity by integrating environmental and sustainability

considerations in the production system with a focus on the well-being of the industry worker. IR4 is considered to be technology-driven, whereas IR5 is value-driven. While the former is considered to emphasize more on digitalization and AI-driven technologies for increasing the efficiency and flexibility of production with human-centricity, sustainability and resilience as a consequential outcome, the latter highlights the importance of research and innovation to support the industry in its long-term service to humanity within planetary boundaries where the human and machine reconcile and work in symbiosis and complementarity to exploit the strengths of each and compensate for their corresponding weaknesses.[5] The human-society centric approach puts core human needs at the heart of the production process which, a priori, envisages a safe and inclusive work environment, physical and mental health and well-being, and worker's fundamental rights, i.e., autonomy, human dignity and privacy. It promotes sustainable and resilient production processes to re-use, re-purpose, recycle natural resources, reduces waste and environmental impact, and a circular economy with better resource efficiency and effectiveness and a higher degree of robustness in industrial production to respond to disruptions and crisis including geo-political shifts and natural emergencies. However, substantial investment from the government is a pre-condition for the success of IR5 and implementation of its core values – human-centricity, sustainability and resilience - to guide societal progress and human development. The Paris Agreement, Sustainable Development Goals (SDGs), various countries' initiatives and legislations about the well-being of future generations, Organization for Economic Co-operation and Development's (OECD) the Economy of Well-being, Better Life Index etc., are already indicative of the journey towards implementing IR5 core values.

NITS Pakistan needs to be contextualized, evolved and implemented fully factoring in these technological and industrial development strands to be able to transform the economic structure into knowledge and technology-led paradigm. It will not only ensure a more equitable and sustainable future of the people but also will lead to the

accelerated catch-up of the technological lag. But for that to happen, it is vitally imperative to address upfront some critically important challenges to guide the policy and institutional processes and research and development thrust to embark on the future course of technological advancement.[6] These, among others, are: the need to embark systemically on the development approach for industry and technology with a prime focus on resource efficiency, societal well- being, human-centricity, sustainability and resilience. Utmost priority has to be accorded to the development of forward-looking albeit targeted techno-social interventions with technology as the enabling tools and societal needs as the ultimate goal e.g., bio-inspired technologies and technologies for energy efficiency, storage, renewable energy etc. Incentive for research institutions, academia and private sector will be the prerequisites to forge a collaborative effort for pursuit of "humanized" and "planet-sustainability" driven innovation and technological development.

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Annex I

Econometric Model

This subsection, through an econometric model, describes and tests the relationship between different variables related to innovation and the economic growth of Pakistan. Multiple linear regression has been conducted with an aim of evaluating the relative impact of the Pakistani NIS through various explanatory and control variables on its economic growth. Following an endogenous growth framework, the model tries to capture the effect of NIS on the economic growth of Pakistan. There is growing empirical evidence to show the positive impact of innovative activity on the economic growth (Ulku, 2007; Wu, 2012). Control variables that have the potential of influencing the economic growth are enclosed in the model for increasing its internal validity and reducing the effects of confounders.

As shown in Figure 14, the performance of the various actors of the NIS and the linkages among them can eventually affect the performance of a country (growth, job creation, competitiveness) via its national innovation capacity. An econometric model, has therefore, been constructed to find the impact of various independent or explanatory variables of innovation on the economic growth of Pakistan. For constructing the model, time series data (1990-2019) has been used on the relevant variables reflecting innovation capacity and GDP per capita of Pakistan. To enhance the internal validity of the model, a couple of control variables have also been included– number of patents granted annually by the IPO in Pakistan and number of scientific and technical journal articles published yearly by the Pakistani researchers.

Equation (1) shows the empirical model in logarithmic form for estimating the relationship between the dependent and independent variables (economic growth and our measure of the NIS). The major advantage for constructing this model was in its parsimony and ready availability of the data needed for its estimation. The null hypothesis for

the model, based on the qualitative mapping of the IS of Pakistan, is that components of NIS of Pakistan have no impact on its economic growth. The major assumption while constructing the model was that there is a strong relationship between a well-functioning NIS and economic growth of a country as shown by the GDP per capita.

All the variables in the model were transformed by taking the natural logarithm. There were two advantages for adopting this approach. First, through the logarithmic transformation, the model fit was improved as all the variables became more normally distributed. Second, an econometric model based on natural logarithms becomes easier for interpreting the coefficients of the independent variables.

STJ (1)

The variables in the model shown in Equation (1) are:

- Y: GDP per capita (constant 2010 US$)
- GERD: Gross domestic expenditure on R&D as percentage of GDP
- HRst: Number of FTE researchers in STEM
- HTE: Value of high-tech exports (current US$)
- PT: Total number of patents granted by IPO
- STJ: Scientific and technical journal articles published

There were a few missing values in the variables HRst, PT and STJ which were replaced by using impute TS package in R. Impute TS package is a popular package for equi-spaced, numeric time series which were used in the econometric model and therefore helped replace the missing values in the data. Before regressing the GDP per capita (Y) on the explanatory variables in the model, two econometric tests for overcoming spurious correlation problem were conducted. These were Augmented Dickey Fuller (ADF) test (Dickey & Fuller, 1979) and Johansen co- integration test (Johansen, 1991; Johansen, 1995).

The ADF test (Dickey & Fuller, 1979) was run to avoid any spurious outcomes while regressing GDP per capita of Pakistan on the

various innovation and control variables. ADF helped determine whether the variables themselves were stationary across the time series (1990-2019). ADF is used to measure the stationarity (or its absence) of the variables in a model. The ADF test is also called the unit root test. The results of the ADF test are reported in Table 9. The null hypothesis for ADF is the non-stationarity of the variable, indicated by the presence of a unit root. Contrarily, the alternative hypothesis (when t-statistics exceed the values at the 5% level of significance), is the rejection of the non-stationarity of the variable; in other words, which means the variable is stationary. Through the stationarity test it was made sure that the time series were flat looking, without trend, had constant variance and there were no periodic fluctuations (seasonality) in them. ADF tests showed that the time series of all the variables i.e., Y, GERD, HRst, HTE, PT and STJ were non-stationary. The explained and the explanatory variables were, therefore, not stationary. Thus, a simple OLS econometric regression could not be run directly for the model shown in Equation (1). Before running the regression, the time series of all the variables were, therefore, made stationary through third order differencing.

After the ADF test, the Johansen co-integration test was conducted (Johansen, 1991; Johansen, 1995) to measure whether there existed a long-run relationship between GDP and other explanatory and control variables in the model. For lag selection for the Johansen co-integration test the VARselect function was used in R for the time series data of all the variables. The optimal lag order computed through the VARselect function was three lags. The commonest approach used for the Johansen co-integration test is the trace statistic approach. Results for the entire model (containing all the six variables) for the trace statistic approach of the Johansen co-integration test are shown in Table 10.

Table 9: Results of ADF Test for the Variables in the Model

Variable	ADF Test Value	p-Value	Null Hypothesis (Presence of Unitroot)
Y	-2.8557	0.2439	Failed to reject
GERD	-2.0523	0.5526	Failed to reject
HRst	-3.0908	0.1536	Failed to reject
The	-1.19	0.8839	Failed to reject
PT	-2.7324	0.2913	Failed to reject
STJ	-3.3865	0.07793	Failed to reject

Table 10: Results of Johansen Co-Integration Test for the Entire Model

Variables	Number of Co-Integrating Equations	Trace Test	5% Critical Value	1% Critical Value
Y and GERD, HRst, HTE, PT, STJ	0	245.75**	102.14	111.01
	1	167.37**	76.07	84.45
	2	105.46**	53.12	60.16
	3	50.24**	34.91	41.07
	4	26.64**	19.96	24.60
	5	10.73*	9.24	12.97

* indicates rejection of the null hypothesis at the 5% level of significance
** indicates rejection of the null hypothesis at the 1% level of significance

Table 10 reveals that at 5% level of significance a long-run equilibrium is confirmed in the relationship between Y and GERD, HRst, HTE, PT and STJ. The trace test value of 10.73 is greater than 9.24 at 5% level of significance which means that the null hypothesis of no long run relationship between Y and other variables is rejected. This confirms the existence of long run relationship between the time series data of the

variables in the model.

The Johansen co-integration test was also conducted for examining separately the long run relationship between Y and each of the variables in the model. The optimal lag order computed through the VARselect function was one lag for all relationships. Table 11 shows the results of the Johansen co-integration test conducted separately for the relationship between Y and all other variables. When run separately, long run relationship exists only between Y and GERD and Y and HRst as null hypothesis can be rejected at 5% and 1% level of significance respectively. The long run relationship between Y and HTE and Y and two controls PT and STJ does not exist as the null hypothesis cannot be rejected. However, the results in Tables 10 & 11 confirm the existence of long-run equilibrium relationship between Y and GERD, HRst, HTE, PT and STJ.

V* indicates rejection of the null hypothesis at the 5% level of significance

** indicates rejection of the null hypothesis at the 1% level of significance

After running the ADF and Johansen co-integration tests and making the time series of various variables stationary, regression analysis of Y on the various explanatory and control variables mentioned earlier was carried out. The results of the regression, as shown in Table 12, indicate that the coefficients of GERD and HRst are not statistically significant. The negative values of R2 in models 1 and 2 depict the insignificance of the coefficients of GERD and HRst. This implies that GERD and HRst which are in fact important inputs to innovation and subsequently economic growth do not have any impact on GDP per capita in Pakistan. Two major components of NIS in Pakistan – GERD and HRst – are not playing any role in the economic growth of the country. More research is needed for understanding whether it is just the low levels of GERD – as discussed earlier – or something else that is preventing any significant impact of it on growth in Pakistan. For example, as discussed earlier negligible or no research has been undertaken by the businesses of Pakistan. Similarly, a future research agenda can also look at why HRst in Pakistan is also not having any impact on the growth of

the country. This research agenda can try to find the utilization of HRst by the Pakistani industry and the relevance of their skills to the needs of the enterprises.

Table 11: Results of Johansen Co-Integration Test run Separately for the Variables

Variables	Number of Co-Integrating Equations	Trace Test	5% Critical Value	1% Critica Value
Y and GERD	0	22.27 *	19.96	24.60
	1	4.96	9.24	12.97
Y and HRst	0	25.68**	19.96	24.60
	1	10.37*	9.24	12.97
Y and the	0	12.53	19.96	24.60
	1	2.37	9.24	12.97
Y and PT	0	14.57	19.96	24.60
	1	5.25	9.24	12.97
Y and STJ	0	14.91	19.96	24.60
	1	2.80	9.24	12.97

In model 3, the addition of HTE into the regression gives surprising results. The coefficient of HTE is highly significant. However, 1 % increase in HTE leads to a 2.1 % decrease in Y. This implies that Pakistan may not be making optimum use of the factors of production for producing HTE. There may be high inefficiencies in producing HTE for which there is the opportunity cost of lesser factors of production for producing other goods and services (light to medium-tech). Producing and exporting high-tech goods is, therefore, not viable for the Pakistani economy. The adjusted R2 also increases substantially in model 3 which shows that 39 % of variance in Y is explained by the main variables – GERD, HRst and HTE in the econometric model.

Table 12: Result of the Regression

Regressions of Log GDP Per Capita on Determinants of Innovation					
Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Constant	-0.001 (0.003)	-0.001 (0.003)	-0.001 (0.002)	-0.001 (0.002)	-0.001 (0.002)
log GERD	-0.005 (0.029)	-0.002 (0.029)	-0.024 (0.024)	-0.045 (0.023)	-0.044 (0.024)
log HRst		0.0043 (0.032)	0.0014 (0.029)	0.0040 (0.034)	0.0036 (0.036)
log THE			-0021*** (0.005)	-0019*** (0.005)	-0019** (0.005)
log PT				-0019** (0.007)	-0019** (0.008)
log STJ					-026** (0.068)
R^2	0.001	0.072	0.461	0.579	0.582
Adj R^2	-0.039	-0.005	0.390	0.502	0.482
N	27	27	27	27	27

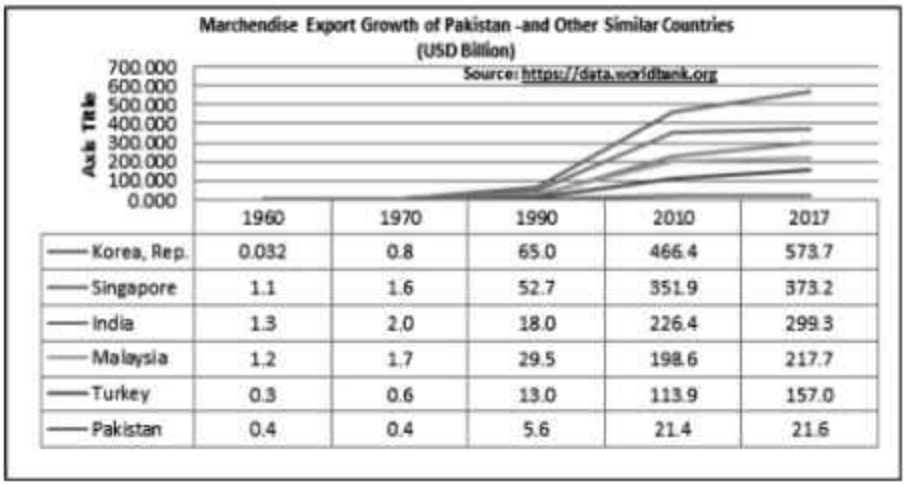
****p<0.001; **p<0.01; -p<0.05*

In model 4, PT was included as a control variable for enhancing the internal validity of the model and reducing the influence of confounders and other extraneous variables. Adjusted R2 goes up from 0.390 to 0.502 indicating the greater strength of the model. Patenting activity has positive impact on the Y of Pakistan as shown by its statistically significant coefficient. 1 % increase in the number of patents granted by the IPO in Pakistan increases the GDP per capita by 1.9 %. The implication is that a stronger IPR and a culture of patenting can improve the innovative capacity of Pakistan and can have important effect on its growth rate.

Finally, the results of model 5 show that the coefficient of STJ – another control variable – is not statistically significant. STJ does not, therefore, impact the GDP per capita growth in Pakistan. The adjusted R2 also goes down to 0.482. The results of the regression models strengthen the findings of the qualitative section of this report. Some major variables

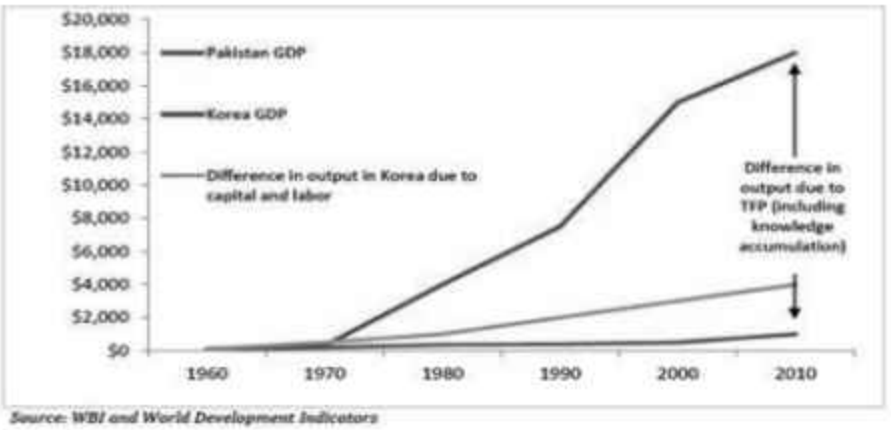
in the NIS of Pakistan – GERD, HRst and HTE – are either not impacting the economic growth of the country or in the case of HTE pulling down the economic growth. Regression shows that the NIS of Pakistan does not have mentionable impact on the growth of the country. The Pakistani NIS is, therefore, very feeble and fragmented as also validated by the qualitative research.

Figure 28: Merchandise Export Growth Comparison



	1960	1970	1990	2010	2017
Korea, Rep.	0.032	0.8	65.0	466.4	573.7
Singapore	1.1	1.6	52.7	351.9	373.2
India	1.3	2.0	18.0	226.4	299.3
Malaysia	1.2	1.7	29.5	198.6	217.7
Turkey	0.3	0.6	13.0	113.9	157.0
Pakistan	0.4	0.4	5.6	21.4	21.6

Figure 29: GDP (per head) Comparison between Pakistan & Korea



Source: WBI and World Development Indicators

Table 13: Export and R&D Investment					
Sr.	**Country Name**	**Export in USD billion (2017)**	**R&D % of GDP - 1996-2016 - 20 years average**	**R&D % of GDP - 2016**	**GCI 2017-2018**
1.	China	2263.3	1.36	2.11	27
2.	United States	1546.3	2.63	2.74	2
3.	Germany	1448.2	2.55	2.94	5
4.	Japan	698.1	3.11	3.14	9
5.	Korea, Rep.	573.7	3.02	4.23	26
6.	Singapore	373.2	2.00	2.16	3
7.	India	299.3	0.76	0.83	40
8.	Malaysia	217.7	0.81	1.3	23
9.	Turkey	157.0	0.63	0.88	53
10.	Pakistan	21.6	0.27	0.29	115

Source: WorldBank Development Indicators

Annex II: List of Nationalized Industries/Entities

Industries Nationalized

Units Taken Over in Karachi

1 Steel Corporation of Pakistan
2 Hyeson's Steel
3 Ali Automobiles
4 Kandawala Industries
5 ROK Industries
6 Haroon Industries
7 Wazir Ali Industries
8 Gandhara Industries
9 Indus Chemical and Industries
10 Valika Cement
11 Karachi Gas
12 Valika Chemicals
13 Karachi Electric
14 National Refinery
15 Pakistan Fertilizer Corporation

Units Taken Over in Punjab and NWFP

1 BECO
2 M.K.Foundary
3 Ittefaq Foundry
4 Rana Tractors
5 United Chemicals
6 Pakistan Cement
7 Ismaeel Cement
8 Central Iron and Steel Works
9 Valika Steel Works
10 Jaffer Steel Corporation
11 Pakistan Progressiv Cement Wah
12 Pakistan progressive Cement Dandot

13 Rawal Pindi Electrics
14 Modern Steel Muredke
15 Multan Electric Supply
16 Karim Industries Nowshehra

Nationalized Banks

1 Habib Bank Ltd.
2 United Bank Ltd
3 Muslim Commercial Bank
4 Australasia Bank
5 Premier Bank
6 Habib Bank Overseas
7 Commerce Bank Ltd
8 Memon Cooperative Bank
9 Lahore Commercial Bank
10 Punjab Cooperative Bank
11 Pakistan Bank Ltd
12 Bank of Bahawalpur
13 Standards Bank

Nationalized Insurance Companies

1 Eastern Federal Union (EFU)
2 United Insurance
3 New Jubilee
4 Adamjee Insurance
5 Habib Isurance
6 Premier
7 Central
8 IGI
9 Union

Nationalized Shipping Companies

1 Pan Islamic Shipping

2 United Oriental Shipping

3 Trans Ocean Shipping

4 Mohammadi Shipping

5 Pakistan Shipping

6 East and West Shipping

7 Gulf Steam Shipping

8 Chittgong Shipping

9 Crescent Shipping

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