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DEPARTMENT OF
SCIENCE & TECHNOLOGY

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

INDIAN ICT SECTORIAL SYSTEM OF INNOVATION (IICTSSI)

United Nations Industrial Development Organization (UNIDO) &
Department of Science & Technology, Government of India

March 2023

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INDIAN INFORMATION COMMUNICATION TECHNOLOGY SECTORIAL SYSTEM OF INNOVATION (IICTSSI) - MEASUREMENT, ANALYSIS AND POLICY RECOMMENDATIONS

UNIDO-DST Survey Report

March 2023 Vienna, Austria

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राज्य मंत्री अंतरिक्ष विभाग
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Minister of State in the Department of Atomic Energy and
Minister of State in the Department of Space
Government of India

MESSAGE

I am pleased to extend my warmest congratulations to the Department of Science and Technology (DST) and the United Nations Industrial Development Organization (UNIDO) on the successful completion of the National Manufacturing Innovation Survey (NMIS) 2021-22. The results of the survey provide significant insight into the state of innovation in India's manufacturing sector. The Government of India has been steadfast in its commitment in promoting the competitiveness of Indian manufacturing and increasing its contribution to the GDP. In the past decade, key policies and programmes have been implemented to stimulate innovation, entrepreneurship and the adoption of new technologies. Additionally, large-scale incentive schemes have been introduced to foster growth and innovation in the manufacturing sector, positioning India as a global manufacturing hub.

The findings of the NMIS 2021-22 can add significant value to the Make in India programme objective, and, the more recent Production Linked Incentive (PLI) scheme. These initiatives aim to enhance manufacturing in various sectors, including electronics, pharmaceuticals, and automobiles, and have already demonstrated positive outcomes. The study's recommendations will undoubtedly strengthen our efforts to address the challenges and opportunities in manufacturing that require immediate attention.

I would once again like to applaud DST and UNIDO for their fruitful collaboration in bringing out NMIS reports and offering recommendations for continued growth and success of the Indian manufacturing sector.

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Secretary
Government of India
Ministry of Science and Technology
Department of Science and Technology

FOREWORD

I am pleased to present the National Manufacturing Innovation Survey (NMIS) 2021-22 report on behalf of the Department of Science and Technology (DST), Government of India. The significance of this study lies in the government's prioritization of the manufacturing sector as a critical driver of economic growth and job creation in India, and the launch of several initiatives to catalyse innovation across the industry.

NMIS 2021-22, a follow up of first Indian innovation survey in 2011, is a focused effort to evaluate the state of innovation in India's manufacturing sector. In collaboration with the United Nations Industrial Development Organization (UNIDO), this survey provides a comprehensive understanding of the Indian manufacturing innovation landscape.

The NMIS 2021-22 findings offer valuable insights into the enabling characteristics and barriers to innovation faced by firms, and closely evaluated the performance of states and sectors in terms of producing new products and services. The detailed analysis of the survey results provides valuable insights into the innovation ecosystem in India. I anticipate this report to be of great interest to policymakers, researchers, and practitioners in the field of innovation and economic development.

Furthermore, the findings and recommendations of NMIS offer strong insights for strengthening the scope of the 5th National Science, Technology and Innovation Policy (STIP) (draft), to enable a holistic ecosystem for science, technology, and innovation that includes academia, industry, government, and civil society, with a stronger vision for manufacturing innovation to bolster the Make in India agenda.

I am confident that these reports will serve as an essential resource for all those interested in the state of innovation in India, providing valuable information that can contribute to the development of policies and initiatives that can foster a more innovative and dynamic manufacturing sector in the country.

(S. Chandrasekhar)

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Preface by Mr. Ciyong Zou, UNIDO Deputy to the Director General and Managing Director for publication of “the National Manufacturing Innovation Survey 2021-2022”

It is with great pleasure that I introduce the National Manufacturing Innovation Survey (NMIS) 2021-2022 report. Jointly conducted by the Department of Science and Technology (DST) of the Ministry of Science and Technology of India and the United Nations Industrial Development Organization (UNIDO), this report aims at comprehensively assessing the state of manufacturing innovation in India towards the achievement of the 2030 Agenda for Sustainable Development, especially Goal 9, and beyond.

As the only specialized agency of the United Nations mandated to promoting inclusive and sustainable industrial development, UNIDO recognizes the critical role that innovation plays in driving economic growth and job creation in the manufacturing sector. We are proud to partner with the DST in this endeavour to assess the state of innovation in India's manufacturing sector.

The NMIS 2021-2022 is a comprehensive study that provides a detailed understanding of the innovation landscape in India's manufacturing sector through a firm-level and systems analysis of innovation. The firm-level component of the survey examines the performance of firms across states, sectors, and firm sizes in terms of innovation processes, outputs, and barriers, and evaluates the innovation ecosystem that affects the innovation outcomes. The sectorial systems of innovation component provide insights into the collaborative processes between innovation stakeholders in specific industrial sectors, such as automotive, pharmaceutical, textiles, food and beverages, and information and communication technologies (ICT).

The findings of the NMIS 2021-2022 serve as a valuable resource to policymakers, researchers, and practitioners in the field of manufacturing, innovation, and economic development. The report highlights the enabling factors and barriers to innovation in the manufacturing sector and provides valuable insights for strengthening the ecosystem for science, technology, and innovation in India. The recommendations contained in this report will not only contribute to the development of national policies and initiatives but can also guide other countries in the region on ways to foster a more innovative and dynamic manufacturing sector.

I would like to express my sincere appreciation to the DST and the technical advisory committee for their valuable contributions to the NMIS 2021-2022. I also extend my gratitude to all the survey respondents who provided their insights and valuable information for this study serving as a public good. UNIDO is eager to continuing the long-standing collaboration with the Government of India in promoting inclusive and sustainable industrial development.

Ciyong Zou
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सत्यमेव जयते

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विज्ञान और प्रौद्योगिकी मंत्रालय
भारत सरकार

Senior Adviser & Head
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PREFACE

The National Manufacturing Innovation Survey (NMIS) 2021-22 is a significant step towards assessing manufacturing innovation in India. The objective of the survey was to evaluate the performance of states, sectors, and firm sizes in terms of innovation processes, outcomes, and barriers, as well as the innovation ecosystem that affects innovation outcomes. The NMIS 2021-22 offers a comprehensive understanding of manufacturing innovation in India from all perspectives.

The Department of Science and Technology (DST), in collaboration with the United Nations Industrial Development Organization (UNIDO), has developed the first Indian Manufacturing Innovation Index (IMII) for guiding decision-making in innovation policy with respect to manufacturing and related services. The significant difference in the IMII score captures the variations in manufacturing across the states.

The "Assessment of Firm-Level Innovation in Indian Manufacturing" report provides a comprehensive and in-depth analysis of innovation activities, outcomes, and barriers in manufacturing firms. Additionally, the NMIS 2021-22 survey produced five reports studying the sectorial systems of innovation within manufacturing sectors, namely, Automotive, Pharmaceutical, Textiles, Food & Beverages, and Information & Communication Technologies (ICT). These reports examine the collaborative processes between innovation stakeholders and the innovation systems available to specific industrial sectors.

The key findings from the study demonstrate that innovation is highly beneficial to manufacturing firms. Over a quarter of manufacturing firms in the country are innovative, and about eighty percent of these firms have used innovations successfully to increase turnover, open new market opportunities, and respond to market and cost pressures. However, the study also reveals that firms face a wide array of barriers to innovation, and innovation activities require perseverance and long-term commitment. Manufacturing firms demonstrate high risk-aversion and lack of entrepreneurial appetite to engage with innovation. Instead of competing for new products that are necessary to compete in the future, firms are still addressing the predominant and immediate demands in the market. These findings call for concerted efforts in strengthening manufacturing policies and bring attention to the need for an innovation strategy for the country, with particular attention to manufacturing.

I would like to express my sincere appreciation to all those who contributed to the creation of this report, including the UNIDO team and the technical advisory committee from DST. We sincerely hope that this report will be of great value as valuable resource and reference note.

(Akhilesh Gupta)

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Acronyms

4IR	Fourth Industrial Revolution
5G	Fifth Generation
ABAP	Advanced Basic Application Programming
ACMA	Automotive Component Manufacturers Association of India
ACTO	Association of Competitive Telecom Operators
ADP	Advanced Digital Production
AI	Artificial Intelligence
AICTE	All India Council for Technical Education
AIoT	Artificial Intelligence of Things
AMOLED	Active Matrix Light Emitting Diode
ARB	Arbitrageur
ASCON	Confederation of Indian Industry Association's Council
ASI	Annual Survey of Industries
ATMP	Assembly, Testing, Marking and Packaging
A-VIEW	Amrita Virtual Interactive E-Learning World
B.Tech	Bachelor of Technology
B2B	Business-to-Business
BHIM	Bharat Interface for Money
BPM	Business Process Management
BPO	Business Process Outsourcing
BTG	Business Transaction Group
BTS	Bartlett's Test of Sphericity
C - DAC	Centre for Development of Advanced Computing
C - DIT	Centre for Development of Imaging Technology
C - DOT	Centre for Development of Telematics
CAGR	Compound annual growth rate
CAP	Creator Accelerator Program
CC & BT	Convergence Communications & Broadband Technologies
CCEA	Cabinet Committee on Economic Affairs
CEO	Chief Executive Officer
CEWiT	Centre of Excellence in Wireless Technology
CHS	Cyber Human System
CII	Confederation of Indian Industry
CMIE	Centre for Monitoring Indian Economy
COAI	Cellular Operators Association of India
CoE	Centre of Excellence
COVID - 19	Coronavirus Disease 2019

CPI	Consumer Price Index
CPS	Cyber Physical System
CRI	Computer Related Inventions
CSC	Common Service Centres
CSIR	Council of Scientific and Industrial Research
CSP	Cloud Service Providers
CXO	Chief Experience Officer
DASI	Data Acquisition Survey Instrument
DASI - V4	Data Acquisition Survey Instrument Version 4
DBT	Department of Biotechnology
DBU	Digital Bank Unit
DCoE	DataKart Centre of Excellence
DEITY	Department of Electronics and Information Technology
DISK	Data Information Statistics and Knowledge
DLI	Design Linked Scheme
DoT	Department of Telecommunications
DPA	Data Protection Authority
DPIIT	Department for Promotion of Industry and Internal Trade
DSAI	Data Science and Artificial Intelligence
DSCI	Data Security Council of India
DSIR	Department of Scientific and Industrial Research
DST	Department of Science and Technology
ECC	Enterprise Resource Planning Central Component
EIC	Enterprise Incubation Centre
EHP4	Enhancement Package 4
EMC	Electronics Manufacturing Cluster
EMPEA	Emerging Market Private Equity Association
ESC	Electronic and Computer Software Export Promotion Council
ESDM	Electronics System Design and Manufacturing
ESSCI	Electronic Sector Skill Council of India
ETBFSI	Economic Times Banking, Financial Services and Insurance
EU	European Union
FAPCCI	Federation of Andhra Pradesh Chambers of Commerce and Industry
FDI	Foreign Direct Investment
FIF	Financial Inclusion Fund
FITF	Financial Inclusion Technology Fund
FOSSEE	Free/Libre and Open Source Software for Education
FTCCI	Federation of Telangana Chambers of Commerce and Industry
FTTH	Fibre to the Home
G2000	Forbes Global 2000
G2B	Government-to-Business
GB	Gigabyte
GCC	Global Capability Centers
GCC Summit	Gulf Cooperation Council
GDP	Gross Domestic Product

GFR	General Financial Rules
GHz	Gigahertz
GI Cloud	Government of India's cloud
GII	Global Innovation Index
GITA	Geospatial Information and Technology Association
GoI	Government of India
GOV	Government
GS1	Global Standards 1
GST	Goods and Services Tax
GVA	Gross Value Added
H1B	Multiple Entry Non-Immigrant Visa
HANA	High Performance Analytic Appliance
HCL	Hindustan Computers Limited
HDFC	Housing Development Finance Corporation Limited
HR	Human Resources
IAMAI	Internet and Mobile Association of India
IAN	Indian Angel Network
IAVC	Indian Academy of Venture Capital
IBEF	Indian Brand Equity Foundation
IBM	International Business Machines
IBPS	India Business Process Outsourcing Promotion Scheme
IC	Integrated Circuit
ICEA	India Cellular & Electronics Association
ICICI	Industrial Credit and Investment Corporation of India
ICT	Information and Communication Technology
ICTPS	Information and Communication Technology Producing Sector
ICTUS	Information and Communication Technology Using Sector
IEC	Information, Education and Communication
IESA	India Electronics & Semiconductor Association
IICTSSI	Indian Information and Communication Technology Sectorial System of Innovation
IIIT	Indian Institute of Information Technology
IIITDM	Indian Institute of Information Technology Design & Manufacturing
IIN	Infosys Innovation Network
IIoT	Industrial Internet of Things
IISc	Indian Institute of Science
IIT	Indian Institute of Technology
IKP	ICICI Knowledge Park
IMPRINT	IMPacting Research Innovation and Technology
IND	Industry
INDIAai	National AI Portal of India
INR	Indian Rupees
INT	Intermediary
IoT	Internet of Things
IP	Intellectual Property
IPR	Intellectual Property Rights
IQ	Intelligent Quotient
IRCTC	Indian Railway Catering and Tourism Corporation

ISBA	Indian Science And Technology Entrepreneurs Parks And Business Incubator Association
ISO	International Organization for Standardization
ISTC	Institutions Supporting Technical Change
IT	Information Technology
ITC	Indian Tobacco Company
ITeS	Information Technology Enabled Services
ITU	International Telecommunication Union
JTG	Joint Telematics Group
K - DISC	Kerala Development Innovation Strategic Council
K - tech	Karnataka Technology
KARSEMVEN	Karnataka Semiconductor Venture Capital Fund
KBI	Knowledge-based Institution
KBITS	Karnataka Biotechnology & Information Technology Services
KDEM	Karnataka Digital Economy Mission
KITVEN	Karnataka Information Technology Venture Capital Fund
KMO	Kaiser-Meyer-Olkin
KPI	Key Performance Indicators
KSFC	Karnataka State Financial Corporation
KSIIDC	Karnataka State Industrial and Infrastructure Development Corporation Limited
KSUM	Kerala Start-up Mission
LIC	Life Insurance Corporation
LLP	Limited Liability Partnership
M&A	Mergers and Acquisitions
M.Tech	Master of Technology
M2M	Machine to Machine
MAIT	Manufacturer’s Association For Information Technology
MCCI	Madras Chamber of Commerce and Industry
MEITY	Ministry of Electronics and Information Technology
MHRD	Ministry of Human Resource Department
MHz	Megahertz
ML	Machine Learning
MoA	Memorandum of Association
MoU	Memorandum of Understanding
MSME	Medium, Small and Micro Enterprises
MTNL	Mahanagar Telephone Nigam Limited
NAAC	National Assessment and Accreditation Council
NABL	National Accreditation Board for Testing and Calibration Laboratories
NAICS	North American Industry Classification System
NASSCOM	National Association of Software and Service Companies
NBFC	Non-Banking Financial Company
NCC	National Conference on Communications
NCR	National Capital Region
NEBPS	North East Business Process Outsourcing Promotion Scheme
NeGD	National e-Governance Division

NEP	National Education Policy
NGIS	Next Generation Incubation Scheme
NIBM	National Institute of Bank Management
NIC	National Industrial Classification
NIC	National Informatics Centre
NICTUS	Non Information and Communication Technology Using Sector
NID	National Institute of Design
NIELIT	National Institute of Electronics & Information Technology
NII	National Information Infrastructure
NIRF	National Institutional Ranking Framework
NIS	National Innovation System
NIScPR	National Institute of Science Communication and Policy Research
NIST	National Institute of Standards and Technology
NITI	National Institution for Transforming India
NITPRIT	National Telecommunications Institute for Policy Research, Innovations & Training
NMCP	National Manufacturing Competitiveness Programme
NMEICT	National Mission on Education through Information and Communication Technology
NM-ICPS	National Mission on Interdisciplinary Cyber-Physical Systems
NMIS	National Manufacturing Innovation Survey
NOPN	National Optical Fibre Network
NPE	National Policy on Electronics
NPIT	National Policy on Information Technology
NPSP	National Policy on Software Products
NSDC	National Skill Development Corporation
NSM	National Supercomputing Mission
NTP	National Telecom Policy
OECD	Organisation for Economic Co-operation and Development
OEM	Original Equipment Manufacturer
ONDC	Open Network for Digital Commerce
OSAT	Outsourced Semiconductor Assembly and Testing
QCI	Quality Council of India
PDPB	Personal Data Protection Bill
PF	Peta Floating Point Operations Per Second
PHDCCI	Progress, Harmony and Development Chambers of Commerce and Industry
PLI	Production Linked Incentive
PPP	Public-Private Partnership
R&D	Research & Development
RBCDSAI	Robert Bosch Centre for Data Science and Artificial Intelligence
RBI	Reserve Bank of India
RI	Research Institution
RICEF	Reports, Interface, Conversion, Enhancements, Forms, and Workflow
RVCE	Rashtreeya Vidyalaya College of Engineering
S&T	Science and Technology
SaaS	Software as a service
SAMEER	Society for Applied Microwave Electronics Engineering & Research

SAP	Systems, Applications and Products
SAS	School of Advanced Studies
SBI	State Bank of India
SBIIT	State Bank Institute of Innovation & Technology
SCL	Semi- Conductor Laboratory
SDO	Standards Development Organization
SEBI	Securities and Exchange Board of India
SEZ	Special Economic Zone
SIAM	Society of Indian Automobile Manufacturers
SIDBI	Small Industries Development Bank of India
SIP-EIT	Support for International Patent Protection in Electronics & Information Technology
SME	Small and Micro Enterprises
SoC	System on Chips
SPECS	Scheme for Promotion of Manufacturing of Electronic Components and Semiconductors
SSC	Sector Skill Council
SSI	Sectorial System of Innovation
STEP	Science and Technology Entrepreneurs' Park
STIP	Science, Technology and Innovation Policy
STP	Software Technology Parks
STPI	Software Technology Park of India
STQC	Standardisation Testing and Quality Certification
TCS	Tata Consultancy Services
TCS BaNCS	Tata Consultancy Services Core Banking Software Suite
TEC	Telecommunication Engineering Center
TH	Triple Helix
T-Hub	Technology Hub
TIFAC	Technology Information Forecasting and Assessment Council
TRIPS	Agreement on Trade-Related Intellectual Property Rights
TRIZ	Theory of Inventive Problem Solving
TSDSI	Telecommunications Standards Development Society, India
TSP	Telecom Service Providers
TSSC	Telecom Sector Skill Council
TVE	Total Variance Explained
TVET	Technical and Vocational Education and Training
UBI	Union Bank of India
UK	United Kingdom
UNCITRAL	United Nations Commission on International Trade Law
UNCOMTRADE	United Nations Commodity Trade Statistics Database
UNCSTD	United Nations Commission on Science and Technology for Development
UNCTAD	United Nations Conference on Trade and Development
UNIDO	United Nations Industrial Development Organization
UPI	Unified Payments Interface
US	United States
USD	United States Dollar
USSD	Unstructured Supplementary Service Data
VARCoE	Virtual & Augmented Centre of Entrepreneurship

VC	Venture Capital
CVC	Corporate Venture Capital
VCF	Venture Capital Fund
VR	Virtual Reality
WIRIN	Wipro-IISc Innovation Network
WITS	World Integrated Trade Solution
WTO	World Trade Organization

Conversion factor

1 Crore = 10 millions
1 Lakh = 100,000

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DST and UNIDO are also incredibly grateful to all the respondents: government policymakers, chief executives of business enterprises, leaders in knowledge-based institutions, directors of financial institutions, venture capital, and knowledge brokering firms for participating in the survey.

Preface

India's aspiration to become a global economic powerhouse will be based on the foundation of a robust industrial sector and its innovative performance. The goal of crafting a US$ 5 trillion economy by 2026-27 will require reinventing Indian manufacturing and innovation activity. If India is to deliver rapid and sustained industrial growth over the next few decades, it needs to strategically focus on building a next generation intelligent manufacturing base where domestic companies become an integral part of global supply chains. India can leverage its strong Information and Communication Technology (ICT) sector and drive supply chain efficiencies and productivity growth through use of ICT deployed at scale. It can harness its soft power advantages to trigger a manufacturing revolution and become a global manufacturing superpower.

In recent years, the Government of India has realised the potential for a new ICT-led model of economic growth and development. It is now moving rapidly to adopt digital technologies and initiatives and investing in digital infrastructure and digital capabilities. It is also working towards strengthening the ICT-based innovations and applications for driving industrial performance, economic growth and social change. Recognising the crucial role of information technology and innovation in the economic development of the nation, Niti Aayog developed a "Strategy for New India @ 75" in 2018. The strategy envisages India as one of the top 50 countries in the Global Innovation Index and suggests that India should aim to spend at least 2 % of Gross Domestic Product (GDP) on research and development. It calls for greater connection between government-industry-academia which is required to identify the changing requirements in manufacturing and prepare an employable workforce. It supports adoption of the Fourth Industrial Revolution (4IR) technologies while maintaining data security, reliability and stability in its communication/transmission. With the unprecedented disruptions of societies and economies caused by the COVID-19 pandemic, such strategies have assumed a greater role in transforming the nation in the post-pandemic world.

Knowledge is emerging as a critical resource, and its better management and flow among people, enterprises and institutions is key to the innovative process. A System of Innovation (SI) represents the strength and quality of the systematically organised interactions and linkages between the stakeholders of the ecosystem; namely government, knowledge-based institutions, industry, intermediaries (institutions supporting technical change, industry associations and incubators), and arbitrageurs (venture capital, angel investors, and financial institutions). The mapping and visualisation of the dynamics of an innovation system are crucial to formulating evidence-based policy for the effective use of resources.

Suitable policy interventions are needed to put India on the global map as the leader in IT and IT-enabled services. The growth of the Indian ICT sector depends on the utilisation of 4IR technologies, as well as the access and adoption of ICT across sectors and organizations. Also, the supply of highly skilled IT personnel and sufficient regulatory support for digital transformation are paramount. UNIDO acknowledges the importance of evidence in optimally deploying policy instruments and targeting available resources (economic incentives and institutions) so that the Indian ICT sector can achieve a competitive advantage. The development of a well-functioning SI is needed to attain competitive advantage as it works as a driver for long-term socio-economic development.

The "Indian Information & Communication Technology Sectorial System of Innovation (IICTSSI) Report" maps and analyses the challenges, potential, and opportunities arising from the innovation system. The analysis is based on data gathered as part of the "National Manufacturing Innovation Survey" conducted by UNIDO in 2021-22. The IICTSSI Report is therefore a source of policy insight for supporting the Government of India to elaborate an evidence-based industrial policy that articulates the role of science, technology, and innovation throughout the economy. The mandate of UNIDO – as one of the specialised agencies of the United Nations system – to provide its member states with capacity-building and policy advisory services is manifest in this report.

The chapters in this report are the result of UNIDO's services in capacity-building, policy analysis, and empirical research on the Indian ICT sector. It aims to enhance the understanding of the role of the core actors, their interactions, and perspectives, thus providing a solid basis for strategic planning, policy, and management of policy actions in order to effectively achieve national targets and goals.

Executive Summary

This report, titled the "Indian ICT Sectorial System of Innovation (IICTSSI) – Measurement, Analysis, and Policy Recommendations" surveys innovation and innovativeness in the ICT sector in India and maps the functioning of innovation and the associated collaborative processes between innovation stakeholders. The survey and analysis were undertaken within the framework of the "National Manufacturing Innovation Survey 2021-22" (NMIS 2021), co-designed with and funded by the Department of Science and Technology, Government of India (GoI).

The report has been compiled for the GoI to inform innovation policy and improve innovation practices within the sector. Furthermore, it aims to facilitate coherent delivery of innovation policy and the establishment of a long-term policy monitoring and management capability for the sector.

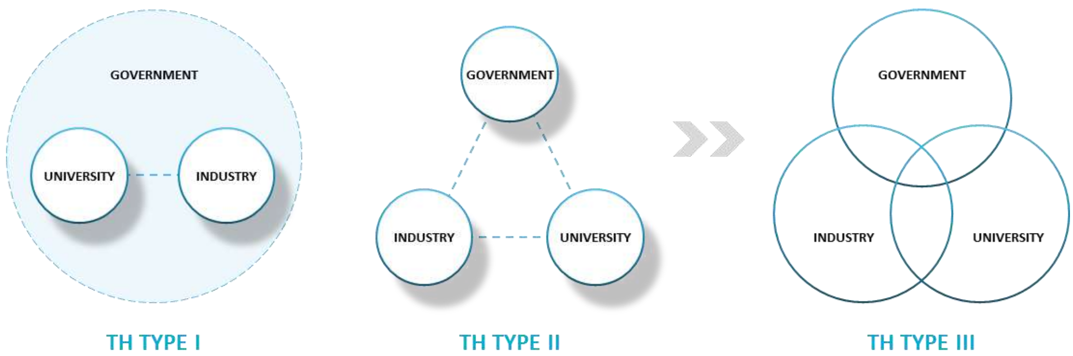
Although there are many significant challenges identified, the policy analysis, implications arising from the analyses, and the policy recommendations to address these implications provide an unprecedented menu of evidence-based development priorities and policy choices to address the challenges. The approach outlined in this report is comprehensive and holistic for mapping and measuring the Indian ICT Sectorial System of Innovation (IICTSSI). It provides an accurate visualisation of the connectivity between the core actors of the IICTSSI, the significant barriers to innovation and innovativeness, and the relative success of current policies in overcoming these barriers. After all, it is not the number of assets India has when considering innovation and innovativeness, but rather how well and coherently they are connected and managed and if they are achieving innovative products and business processes and subsequent economic value.

It is imperative that policymakers view the analysis, implications, and recommendations in light of India's economic performance in an emerging economy and in the context of the COVID-19 pandemic, which hit all sectors across the globe.

The analysis of the GoI policy documents, the mapping and measurement of the IICTSSI in terms of analysing linkages between (and within) actor groups, barriers to innovation and the success of policy instruments disclose the significant key policy analysis findings, the major implications from the analysis, and the recommendations that stem from them.

In the specific case of the ICT sector, our assessment is that the IICTSSI falls into the category of a Triple Helix (TH) Type III, as per the traditional framing of the TH model. In the TH-Type I the three spheres of the actors are strongly institutionally defined, however, work in isolation leading to the local technological knowledge also being kept isolated. With TH Type II, mechanisms of communication between the actors are strongly influenced by the market and technological innovations, and the point of control is at the interfaces and consequently new codes of communication are developed. In TH-Type III, the three actors assume each other's roles in the institutional spheres as well as the performance of their traditional functions. With the emergence of TH-Type III, a complex network of organizational ties has developed, both formal and informal, among the overlapping spheres of operations. The transformation of the knowledgebase is of particular relevance. After having incorporated research as an additional mission beyond teaching, universities recognise their role in the pursuit of economic and social development. Hence, universities take on entrepreneurial tasks such as marketing knowledge, increased technology transfer and the creation of spin-offs and startups, as a result of both internal and external influences. Similarly, the importance of industry emerges in the process of knowledge generation and the creation of skilled human capital.

FIGURE 1: Triple Helix types



Consequently, there is the need to maintain and strengthen the relationships between the actors of the IICTSSI, thus fostering a favourable environment for innovation.

Based on this observation, the inter and intra interactions that need attention are:

- Fostering joint research between industry players, similarly for government and knowledge-based institutions, as well as government and industry, particularly in strategic areas such as quantum computing.
- Promoting secondments between knowledge-based institutions and the ICT industry as programmes benefit individuals and companies by developing new skills, boosting engagement and increasing retention. They can also resolve specific problems and needs of the ICT sector.
- Better connectivity between the knowledgebase and intermediaries in particular industry associations in terms of technical knowledge dissemination; and
- Closer linkages between the knowledgebase and arbitrageurs to facilitate the process of ideation to market.

Secondly, the analysis highlights that relationships between actors in the IICTSSI are imbalanced, hindering the flow of knowledge and information crucial to the innovation process. This is mainly due to a suboptimal understanding of each actor's role within an effective system of innovation and the terms and conditions are unfavourable to meaningful participation. Consequently 'Industry 4.0', 'Policy Function', 'ICT Knowledge and Stocks', 'Human Capital' and 'Finance', emerge as the main underlying barriers to innovation within the IICTSSI.

From the perspective of '<u>Industry 4.0</u>', the associated variables are: 'Lack of understanding of I4.0 technologies', 'Lack of access to I4.0 technologies', 'Cost of I4.0 technologies' and 'Lack of infrastructure for I4.0'. Manufacturing in the ICT sector is rapidly changing, particularly with the adoption of 4IR technologies. Manufacturers across sectors are making in-house investments in basic enterprise systems such as ERP, CRM and PLM. However, a basic awareness of converting the concepts of I4.0 into actual business opportunities as well as the challenges in coming up with use cases (e.g., combinations of technologies) as comprehensive solutions are still lagging.

Areas beyond the control of Indian firms, such as telecom infrastructure for 5G, are lacking global levels of adoption, constraining their adoption and the benefits from adopting them (e.g., low latency, high bandwidth telecom using 5G for real-time decision-making). The lack of understanding and the cost of I4.0 arise from the information asymmetry between traditional manufacturers and technology service providers, as these technologies are emerging areas.

With respect to '<u>Policy Function</u>', the associated variables are: 'Lack of legal framework', 'Restrictive public/ govt regulations', 'Lack of clear national innovation strategy,', and 'Lack of higher resolution regulations. The convergence of various technologies like the ubiquity of the Internet, emergence of an app economy, and pervasiveness of social media have caused a paradigm shift in the Indian ICT industry. Consequently, this poses several policy and regulatory challenges. With respect to consumer and producer welfare, India's adoption of consumer welfare standards is not very dynamic, which has an impact on competition and innovation and also means that MSMEs and startups are unable to compete with large multinationals. Specific issues for the Indian ICT sector include the need to evaluate patenting norms for software in India in line with other places such as the UK, Europe and Japan.

Increased ICT adoption reduces information asymmetry and information flows are vital for the innovation process. However, in the case of the IICTSSI, '<u>ICT Knowledge and Stocks</u>' emerges as a barrier to innovation with the following associated variables: 'Rate of access to ICT', 'ICT capacity', 'Lack of technology (technology gap)' and 'Lack of information (knowledge gap)'. As digital technologies are increasingly embedded in products across their lifecycle from conceptualisation, design, manufacture, operation, service and end-of-life, traditional manufacturers face the issue of information asymmetry when compared to digitally savvy newcomers or technology partners with whom they need to collaborate and negotiate.

'Human Capital' is a collective resource that emerges from the knowledge, skills, and abilities of employees. <u>Human capital silos</u> as a perceived barrier underscores the question of how knowledge can be generated, accessed, and transmitted throughout a system to deliver innovation activities. This is a crucial issue particularly with the paradigm shift caused by digital transformation and 4IR. Consequently, the emergent variables associated with the barrier are the 'Lack of technically trained manpower', 'Quality of technically trained manpower' and 'Lack of willingness to share knowledge'.

This siloed approach becomes a barrier for adopting emerging concepts. For organizations to be successful in making these products efficiently using I4.0, human capital with a holistic perspective about the application of these technologies is important. Knowledge of operating software from basic spread sheets to programming of machine tools or robots will become a basic necessity across industries and functions. Businesses need to start restructuring around micro-enterprises with all necessary skill sets, and not the traditional functional approach.

Finally, with respect to policy success, policy instruments were analysed in terms of supply-side measures (services and financial) and demand-side measures. The study results indicate that in general policy instruments are successful, however the most unsuccessful policy instruments reported by all actors are the demand-side measures of 'Labour mobility (laws, incentives)' and 'Regulation'. Labour mobility is multi-faceted and speaks to the ability of a worker to move across jobs, occupations and sectors to take advantage of new opportunities. This is even more crucial given rapid technological changes in ICT job roles and the proliferation of Industry 4.0 technologies which has impacted labour mobility in the ICT sector.

Regulation as a barrier is reflective of the need to clearly articulate high-level goals and visions down to all levels of the system and with respect to industry, to small and medium sized firms, with a reduction in the level of complexity thus better enabling navigation of the sector.

In addition, each actor has a specific view on effective or ineffective policy instruments, which needs to be considered when selecting a policy mix. Policy selection should not be an arbitrary process. It should be based on evidence and reflect the needs of the actors in the system and be in line with India's overall strategic orientation.

The major implications of the analysis outlined in the report are that better externalities need to be generated from the public goods of funding and support. Phrased differently, innovation inputs need to be better translated into innovation outputs. This requires further strengthening of the nexus between the knowledgebase, industry and research institutions, with a view of global changes and best practices.

In addition, the remoteness of actors causes them to be relatively independent of the policy-making process, especially in terms of wielding influence in configuring and calibrating policy to exploit knowledge and intermediating the flows of technical know-how. The present public infrastructure needs to be strengthened to create a fabric of vibrant linkages that supports innovation. What is required is a widely accepted conducive environment in which organizational rigidities are overcome.

The IICTSSI Report demonstrates the value of comprehensive survey and the critical importance of mapping and measurement to guide the discussion for evidence-based and collaborative policy making, execution, monitoring and impact evaluation. A periodic repeat of systematic mapping and measurement of the IICTSSI in two to three years is strongly advised and can help to ascertain the effects of policy choices, implementation, resource application, and hence innovation and innovativeness in the Indian economy.

1. Project Context

Project Context

The "National Manufacturing Innovation Survey (NMIS) 2021-22" is a follow-up to the Department of Science and Technology's (DST) (GoI) first "National Innovation Survey" held in 2011. The 2011 survey results showed that most of the innovations in Indian firms were in the form of introducing new machines, or improvements to existing products and processes (DST, 2014). The study found these firms at par or ahead of their competitors regarding improved ranges of products (better quality and standards), besides improving production capacity and reducing environmental impacts. Such firms were largely privately owned small companies and relied on domestic financial institutions. While these innovative firms struggled with cost factor and availability of skilled manpower, more than 50% did not employ scientists or engineers but reported that access to knowledge and information was a critical barrier.

The decade that followed the 2011 National Innovation Survey saw the launch of key policy initiatives, especially the "Make in India", "Startup India" and the "Aatmanirbhar Bharat Abhiyan", among others, positioned to strengthen and boost the country's manufacturing sector outputs where innovation and entrepreneurship programmes were prioritised. The scope of indigenous innovations and innovation ecosystems thus received greater impetus in this period. In 2019 the DST followed up with the planning of the second nationwide innovation survey and partnered with the United Nations Industrial Development Organization (UNIDO), with greater attention to manufacturing and associated services spread across large, medium, small and micro enterprises. It emphasised the role and separately studied the impact of this ecosystem and its actors on innovations in specific sectors.

1.1 The National Manufacturing Innovation Survey 2021-22

The National Manufacturing Innovation Survey (NMIS) 2021-22 was designed as a 2-pronged survey where the DST-UNIDO collaboration adopted a 360-degree approach to measuring innovation performance at the level of manufacturing firms, and assessing innovation processes, its barriers and support measures at the ecosystem level of industrial sectors. To this end, the survey was designed with two specific components – the Firm-Level Survey and the Sectorial System of Innovation (SSI) Survey.

The objective of the Firm-Level Survey was to capture insights regarding activities impacting innovations in a firm, across a broad spectrum of product and business process innovations and understand the various factors enabling and/or limiting innovation activities. On the other hand, the SSI Survey aimed to measure the innovation system available to specific industrial sectors to examine how manufacturing firms accessed information, knowledge, technologies, practices, and human and financial resources, and what linkages connect the innovating firm to other actors in the innovation system (laboratories, universities, policy departments, regulators, competitors, suppliers, and customers). Thus, with an overarching scope to strengthen, improve and diversify India's manufacturing with targeted and evidence-based innovation policy, the NMIS 2021-22 Survey was launched in February 2021.

TABLE 1: Overview of Firm-level survey and SSI survey

The Firm-Level Survey assessed the following: *(Broad overview)*	The SSI Survey assessed the following: *(Broad overview)*

• Types of innovations in manufacturing firms
  • Product innovation
  • Business process innovations in (e.g., operation, product/business process development, marketing & sales, procurement, distribution & logistics, administration, and management)
• Innovation activities
• Sources of information, collaborations, resources
• Factors hampering innovation activities.
• Impacts of digitalisation, infrastructure, IP
• Impact of COVID-19 pandemic
	• Innovation actors (firms and non-firm actors) for their networks (density, distribution, directionality, symmetry of intra- and inter-linkages of actors)
	• The role and impact of actors and institutions on innovation activities in firms
	• Impact of policy instruments (fiscal, monetary, regulatory, standards and others)
	• Barriers to innovation

With a stratified random sample representing micro, small, medium and large manufacturing companies, the Firm-Level Survey targeted 10,139 firms across 58 manufacturing sectors (as per the national industrial classification 2008[1]) across the 36 states and union territories in the country. The SSI Survey targeted the innovation systems of 5 key manufacturing sectors critical to the Indian economy, prioritised by their gross value-added (GVA) and their presence across the country, impacting state-level and national policies and strategies. These 5 sectors are: Food and Beverages, Textiles and Apparel, Automotive, Pharmaceuticals, and Information and Communication Technologies (ICT). A stratified random sample close to 7,851 firms and 1,000 non-firm actors were targeted under the SSI Survey across India. The outcomes of the Firm-Level Survey are separately reported, while this report features the SSI Survey objectives and findings.

1.2 Significance of the Sectoral Systems of Innovation Survey

The SSI Survey postulates that for a firm to be effective in the innovation process, a conducive environment that consists of an effective support infrastructure of actors is critical. Connectivity between them that is fluid and dynamic will be pivotal in aiding access to the requisite, knowledge, skills, and resources. Hence, the survey aimed to map the innovation capability of manufacturing firms to such actors and institutions of sector-specific systems of innovation and also regional systems of innovation, and national systems of innovations. To this end, the interactions (or linkages) and the density of these linkages to various ecosystem actors were studied to achieve a clear understanding of these relationships in empirical terms to assess the flow of communications and information and assets between knowledge-based institutions, research and development agencies, industry bodies, government agencies, financial institutions, startup incubators, institutions supporting technical change, and arbitrageurs.

The survey particularly took cognisance of the innovation and manufacturing mandate of NITI Aayog, the apex policy advisory body to the GoI[2]. In its strategic recommendation for improving India's manufacturing sector outcomes, NITI Aayog strongly recommended the need for promoting latest technology advancements and predicted a defining role for Industry 4.0 intervention in shaping the sector and achieving an ambitious double-digit growth (NITI Aayog, 2018). Further, the agency has also been assessing the nation's priorities and strategies for consolidating and strengthening science and technology (S&T) initiatives to amplify technology development and commercialisation. Since the 1990s, the Government of India has deployed technology incubators as an important policy tool for S&T entrepreneurship (Surana et al., 2018). The DST has been at the forefront of designing and establishing science and technology entrepreneurship parks, incubation systems, and technology business incubators to build close linkages between universities, academia, R&D institutions and the industry, including MSMEs, and also to generate employment[3]. These initiatives led to strong technology-based entrepreneurship and startups in the country, and set motion to various policy frameworks and initiatives, such that most incubation programmes in the country today leverage support offered under various ministries, who also have a manufacturing stake. The public sector enterprise model for biotechnology-based startups by the Department for Biotechnology (DBT) has been highly successful in converting research into products and attracting investments and has impacted the pharma and life-sciences landscape in the country. Similarly, for strengthening IT and digital startup linkages with markets, the Ministry of Electronics and Information Technology (MeitY) has been offering risk capital and low-cost loans. With their broader mandate, the Ministry of MSME and the Department for Promotion of Industry and Internal Trade (DPIIT) have designed and implemented several startup programmes, and importantly brought SME collaborations to sector-specific incubators, thus offering a stronger market access to entrepreneurs.

India's technology and innovation agenda took a strong leap over the last decade when the Government of India launched a series of high-powered initiatives to amplify and catalyse the pace of innovation and entrepreneurship with greater emphasis on the startup ecosystem. The "Startup India" mission was put in place to tackle the complex, lengthy regulatory processes for startups and introduced tax incentives and high-risk funding to startups[4]. The "Atal Innovation Mission" brought sector-specific attention to the startup agenda for innovation and entrepreneurship incubation infrastructure across the country and widened

[1] National Industrial Classification (NIC) 2008 is an essential statistical standard for developing and maintaining a comparable database according to economic activities: https://www.ncs.gov.in/Documents/NIC_Sector.pdf

[2] About NITI Aayog: https://www.niti.gov.in/objectives-and-features

[3] Science & Technology Entrepreneurship Park (STEP): https://www.nstedb.com/institutional/step.htm

[4] The Startup India initiative (under DPIIT) was launched to improve the innovation ecosystem and handhold, fund and incentivise startups and improve industry-academia partnerships through incubation services: https://www.startupindia.gov.in/content/dam/invest-india/Templates/public/Action%20Plan.pdf

its scope to schools and other academic institutes[5]. Further, the "Invest India" programme was launched to catalyse investments in manufacturing, technologies, incentivising innovations and other areas of trade and commerce[6]. The increased access to risk capital in technologies in this period have played a key role, such that Bain (2022) reports that VC investments in India pegged at US$ 38.5 billion in 2021 and have positioned India as the third largest startup ecosystem in the world[7].

The SSI Survey was positioned to examine how such policy and institutional arrangements (innovation/incubation programmes established in various technology and higher education institutes) across the country have impacted the collaboration of firms with academia, startups and investors for commercialising innovations, thereby addressing various transaction-related problems endemic to lab-to-market journeys. Studies show that traditional R&D institutions in the country, however, continue to prioritise "blue-sky research" over "application-oriented research" and on the other hand, several recent studies have brought attention to the challenges faced by India's public-funded labs in commercialising their research outputs. While technology interventions have direct impact on productivity, accessing capital in manufacturing technology-based projects continue to be a challenge, owing to the longer gestation period before they yield returns. As Nandagopal et al., (2013) point out, Indian firms continue to be traditionally risk-averse, and are inclined to invest in non-technology-based sectors like retail, banking, infrastructure, entertainment, among others. The SSI Survey made crucial inclusion of the role of arbitrageurs, such as the venture capitalists and knowledge brokers, as these actors have increasingly been decisive in the innovation process in bringing internal and external knowledge and high-risk investments that result in new business models and new types of companies.

1.3 Relevance of the 5 Manufacturing Sectors Prioritised by the SSI Survey

With the goal of significantly increasing the manufacturing sector contribution to the GDP from 16.5%, the "Make in India" mission is a major policy initiative launched in 2014 aimed to make India a high-tech manufacturing hub[8]. The mission now targets 27 manufacturing sectors that has key significance to the economy and the 5 manufacturing sectors identified for the SSI Survey have significant priority in the Make in India mission.

India's food processing is globally one of the largest, with a significant number of registered factories across the country attributing to the direct employment of 1.9 million people, with 8.9% MVA (food and beverage along with tobacco) (UNIDO IAP, 2023). Despite being a major trader and exporter of agriculture products, India's export processed food is less than 10% owing to critical impediments across supply chain infrastructure, production and processing, inefficient capacity utilisation, quality and safety challenges, and slow product and technology interventions (RBI, 2020). Similarly, the other large sector in the survey, the textiles and apparel sector, has a prominent manufacturing presence in many states and provides direct employment to more than 45 million people and contributes close to 7% of MVA[9]. In 2021-22 the Indian textiles and apparel industry was valued at US$ 152 billion and accounted for a 4% share of the global textile markets. Yet the highly fragmented sector is also labour and raw material intensive and is mired with productivity challenges that tend to undermine value chains and their backward linkages. For instance, more than 80% of the 50 million spindles and 842,000 rotors deployed by textile mills are found to be outdated or inefficient[10].

The SSI Survey aimed to also gather learnings from actor collaborations, institutional best practices, challenges, technology leapfrogging trajectories and other aspects of systems of innovation in three high performing sectors, such as the automotive, pharmaceutical and ICT sectors. With a 20.1% contribution to the manufacturing GDP, the automotive sector is a top driver of macroeconomic growth and technological development in the country (UNIDO IAP, 2023). With robust performances, the ICT and pharmaceutical sectors are the world's key players. India's pharmaceutical sector is the third largest in volume, driven by export markets and the expansion of Indian healthcare that has resulted in innovative products, processes and services, thereby positioning India as the pharmacy of the world[11].

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[5] The Atal Innovaiton Mission driven by NITI Aayog established numerous innovation and entrepreneurship centres in schools, universities, research institutions, private and MSME sectors: https://www.aim.gov.in/overview.php

[6] Invest India: Investment Promotion and Facilitation Agency. Invest India.

[7] Economic Survey: India becomes third-largest startup ecosystem in the world. Mint: https://www.livemint.com

[8] The Make in India Mission: https://www.pib.gov.in/PressReleasePage.aspx?PRID=1738170

[9] Textile Industry in India - Garment & Apparels Market in India: www.investindia.gov.in/sector/textiles-apparel

[10] India should continue investing in modern, efficient spinning technology to remain globally competitive: https://www.indiantextilemagazine.in/india-should-continue-investing-in-modern-efficient-spinning-technology-to-remain-globally-competitive/

[11] India has become pharmacy of the world: https://www.moneycontrol.com/news/india/india-recognised-as-pharmacy-of-the-world-fm-9759651.html

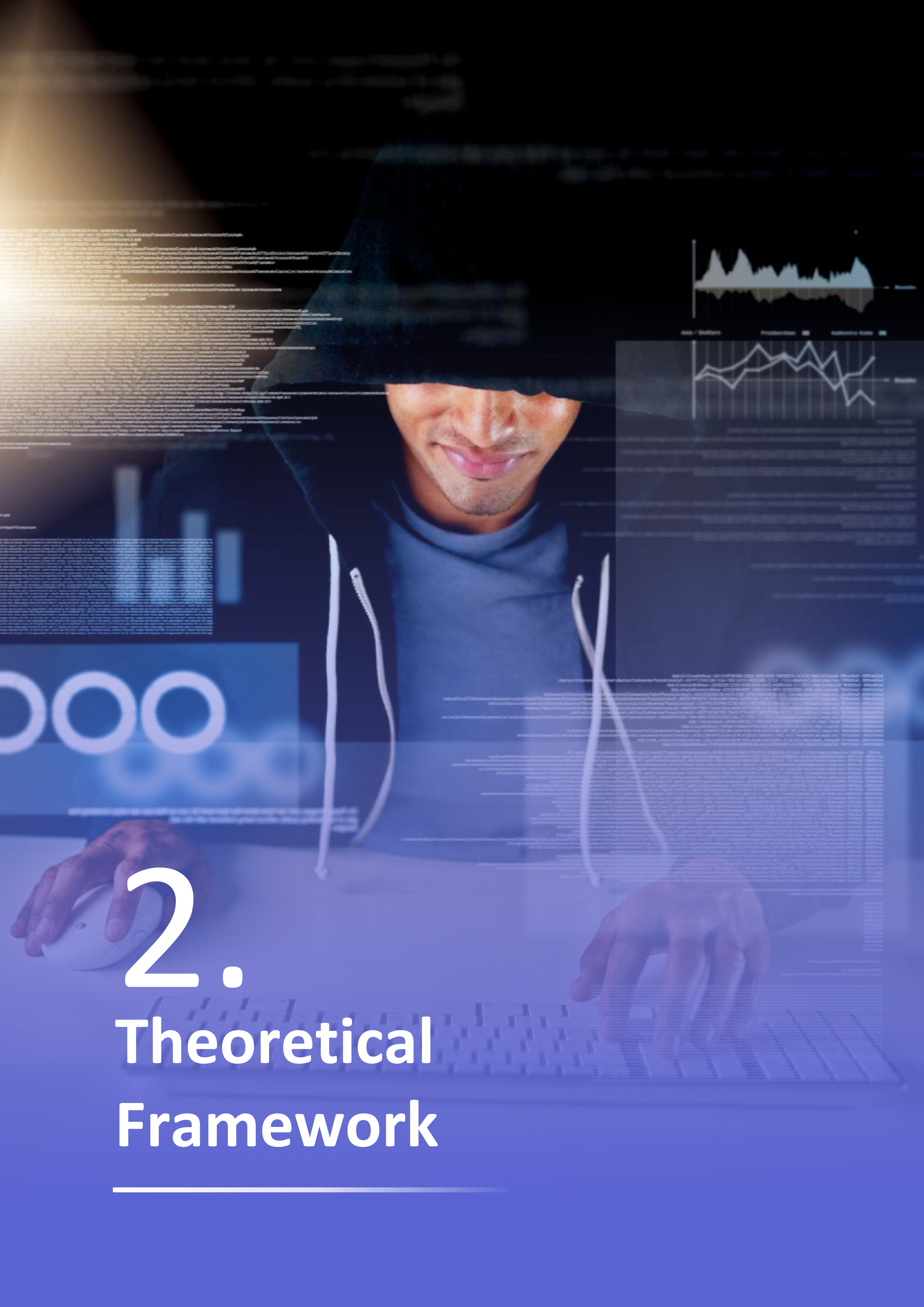
1.4 SSI Survey to Strengthen Manufacturing Innovation as a GoI Policy Imperative

The Make in India ambitions were further boosted in 2020-21 with the launch of the Production Linked Incentive (PLI) scheme across 14 key manufacturing sectors, to incentivise import substitution by domestic production in strategic growth sectors[12]. Invariably, the domestic manufacturing ecosystem and supply chains are critical to the success of the PLI scheme. Similarly, the "Gati Shakti" programme was launched in 2021 to improve infrastructure and connectivity for faster and more efficient movement of goods and services, and impact manufacturing and business operations at large[13]. Besides technological leapfrogging, world-class innovation capabilities, skills and investments, the Government of India's efforts in improving the investment environment has been critical. The country saw FDI inflow catch great momentum between 2014-22 and by 2019 India was recognised as one of the most attractive emerging markets for investments[14]. However, the FDI share in Indian industries seems to continue to largely benefit non-manufacturing sectors such as software businesses. Nevertheless, the hardware, pharma-biotech and electrical equipment sectors, among others, with strong product sophistication and better production capabilities, attract strong foreign direct investment (FDI) inflow, especially with their digital capabilities in manufacturing and product offerings[15]. The global shifts in advanced digital manufacturing with self-correcting intelligence has been a game changer since the pandemic and has reflected in investment interests as well.

The SSI Survey has attempted to capture the dynamics of communication, stocks and flows of knowledge and organization by introducing the notion of an intersection of exchange relations that feed back into institutional arrangements. The aim has been to understand how co-evolution between the layers of institutional arrangements and evolutionary functions can be conceptualised, in relation to the division of innovative labour among both institutions and functions. This is particularly important when crafting policy for the effective use of resources. Thus, by generating evidence of the barriers and challenges to technological learning, innovation and development, and technological up-gradation of Indian industries the survey findings shall be used for devising policies, programmes, and partnerships to strengthen innovation outcomes and benefits.

The project was supported by the UNIDO Facility for International Cooperation for Inclusive & Sustainable Industrial Development (FIC-ISID), a joint initiative of the DPIIT and UNIDO, with the aim to catalyse inclusivity and sustainability in manufacturing industry development. Five major business membership organizations, respectively the India SME Forum (ISF), the Federation of Telangana Chambers of Commerce and Industry (FTCCI), the Federation of Andhra Pradesh Chambers of Commerce and Industry (FAPCCI), the Madras Chamber of Commerce and Industry (MCCI), and the PHD Chamber of Commerce and Industry (PHDCCI) were key partners in data-collection across India's 28 states and 8 union territories. The survey completed the data collection in early May 2022.

[12] The PLI Scheme: https://www.investindia.gov.in/production-linked-incentives-schemes-india
[13] Gati Shakti: https://dpiit.gov.in/logistics-division
[14] Emerging Markets Private Equity Association 2019 Survey: https://www.globalprivatecapital.org/app/uploads/2019/05/2019-lp-survey-final-web.pdf
[15] FDI in India 2021: https://www.makeinindia.com/policy/foreign-direct-investment



2. Theoretical Framework

Theoretical Framework

Innovation is increasingly viewed as the salient ingredient in the sustainable growth of the modern economy. An economy must continuously absorb new knowledge and develop new skills and capabilities to avoid erosion of competitiveness and facilitate economic growth and diversification. Historically, countries that fostered innovation by developing interconnected innovation systems have proven to be more capable of generating new knowledge and translating it into business opportunities and thus wealth creation (Freeman, 1987; Nelson and Rosenberg, 1993; Lundvall, 1992, 2016; Chaminade et al., 2018). An innovation system refers to a set of institutions that contribute to the development, diffusion and application of scientific and technological knowledge (Dosi, 1988). Studies have shown that well-functioning innovation systems are essential to catch up with advanced economies (Kim, 1992, 1997; Kim and Nelson, 2000; Fagerberg and Srholec, 2008; Malerba and Nelson, 2013; Fagerberg et al., 2017; Shekar, K. C., & Joseph, K. J., 2022).

Innovation systems are framed at different scales, including national, sectoral and local/regional (Chaminade, 2018). The framing of an innovation system involves different types of network and interactions depending on the driving interest, practices, behaviours and the working environment in general. The considerations for building these networks may vary depending on the context and scale of the operations/activities happening among the actors. These networks will evolve based on the behaviour and routine among the actors and their organizational context (Hall, Mytelka, and Oyeyinka 1997; Jacob 2016). However, knowledge and learning remain the central points to the networks (Moschitz et al., 2015). The establishment of such networks for building a system involves breaking barriers and reconstructing channels for knowledge flow. This is done by setting interactive processes, sharing best practices and learning from prior experience, while overcoming failures and filling gaps. The form and the performance of learning approaches may vary from one sector to another, depending on different patterns such as the roles, habits, mode of operation, competencies, demand, among others (Mytelka and Smith, 2002). This suggests a systemic way of establishing a framework that allows interactions among the different groups and contributes to the use of knowledge for the collective/mutual interest of the actors.

Since innovation is a collective action that involves a multitude of actors who co-operate and compete in networks and who are stimulated and constrained by institutional settings in different sectors, we use the concept of 'Sectorial Innovation Systems'. The rationale for using this framework can be further justified on the ground that it encompasses all the relevant aspects that might possibly influence innovation and economic growth and is suitable to analyse the inter-related character of innovation processes. In this backdrop, this chapter presents the theoretical underpinnings for the approach used in mapping and measuring the Indian Textiles and Apparel Sectorial System of Innovation (ITASSI). It introduces the concept of the Sectorial System of Innovation (SSI), as well as reviews the elements that constitute its early conceptualisation, through a review of the evolution of seminal literature. Based on this, the chapter outlines the traditional Triple Helix Model of government-university-industry (Etzkowitz and Leydesdorff, 2000) interactions as well as its extension.

2.1 Theoretical Underpinnings

The organization and development of innovation have gained much attention from different perspectives. The traditional notion of innovation as an end provides a narrow view of innovation and the potential it has on societal development in different dimensions. Whereas the consideration of innovation as a process that engages a chain of activities that can lead to different types of innovations that then have diverse socio-economic impacts is more prevalent today. An innovation system considers innovation as a process and considers how the actors interact among themselves to undertake innovation activities. They consider the inputs to innovations and the channels leading to the expected outputs. This does not mean the use of the linear model of input-output that has been used for some time as a way of linking science to innovation. Rather, it considers the complexity of the processes and the interactions among actors involving learning activities and the use and transfer of knowledge (Etzkowitz and Leydesdorff, 2000). The available literature on innovation capabilities in the Indian industrial sector is mostly based on STI indicators that focus more on R&D activities and the creation of access to codified knowledge (Basant, 1997; Basant and Fikkert; 1996; Kartak, 1985; Kumar and Siddharthan, 2013; Shekar, K. C., & Paily, G., 2019). For instance, Basant and Fikkert, (1996) examines the effects of domestic and foreign technology purchases as well as R&D activities in enhancing the productivity of firms in India. The study shows that between 1974-75 and 1981-82, domestic and international R&D spillovers and foreign technology purchases are highly statistically significant as compared to own R&D expenditures. Even though technological strategies greatly contribute to the productivity growth of Indian enterprises it is not directly reflected in export performance, which is also considered as an important indicator of a firm becoming more innovative (Lall and Kumar, 1981). It is highly evident in high technology sectors rather than medium and low technology sectors (Kumar and Siddharthan, 1994). A sector-specific study conducted by Bhaduri and Ray (2004) examines the technological capability of exporting firms in the electrical and electronic equipment industry. Firms in this industry mainly depend on know-how rather than know-why capabilities. In addition to these approaches, innovation systems research focuses on interactive learning, interdependence and non-linearity wherein institutions play the central role (Joseph, K. J, 2009; Shekar, K. C., & Joseph, K. J., 2022). The innovation system perspective has become a widely used analytical tool for academic research, policy formulation and implementation which aim at effective relationships among the agents and increase the innovation efficiency (Dosi et al., 2006). Therefore, the innovation system, which has by now emerged as the most popular approach in innovation studies, involves a more holistic framework to study the inter-related character of innovation processes as it focuses on the interdependencies among the various agents, organizations and institutions while underlining the need for R&D (Freeman, 1987; Dosi et al., 1988; Lundvall, 1992; Nelson, 1993; Edquist, 1997; Shekar, K. C., & Joseph, K. J., 2022).

Since the late 1980s, innovation system concepts have been developed and presented primarily by innovation researchers as a response to the shortcomings of neoclassical attempts to explain innovation and technological progress (Edquist, 1997). According to Christopher Freeman, "…systems of innovation are networks of institutions, public or private, whose activities and interactions initiate, import, modify, and diffuse new technologies" (Freeman, 1987). The innovation system, with a focus on technology and information flows between people, businesses, and institutions, and was created as a tool to understand the innovation process (Lundvall, 1985). Innovation systems help identify how to stimulate innovation and what inhibits its development and have become a viable method for researchers and policymakers to study the innovation process, especially in emerging and developing economies (Weber and Truffer, 2017; Shekar, K. C., & Joseph, K. J., 2022).

Different types of innovation systems have emerged since the identification of the concept of innovation systems such as the National Innovation System (NIS) (Lundvall, 1992; Freeman, 1987; Edquist, 1997; Lundvall, 2007; Nelson, 1993), Regional Innovation System (RIS) (Saxenian 1994; Cooke & Uranga, 1997), Sectoral System of Innovation (SSI) (Malerba, 2002; Breschi and Malerba, 1997) and technological systems (e.g., Carlsson and Stankiewicz, 1991), also known as a technological innovation system (Bergek et al., 2008; Hekkert et al., 2007). The NIS as the common analytical framework for innovation to economic growth. This considers a country as a unit of analysis. It provides the macro indicators in regard to interactions among actors, organization structures, institutions and learning processes as well as the facilitation. It considers interactions among actors as key for innovations. Actors can be firms' organizations and non-firms' organizations (universities, R&D organizations) (Chaminade et al., 2018; Shekar, K. C., & Paily, G., 2019). The categories of organizations may generally be grouped as knowledge producers and knowledge users. Whereas the system is based on these categories and the interactions among them, institutions are very important in the innovation systems. In this context, institutions are considered as a set of routines, behaviour, regulatory tools, and policies (Edquist, 2005; Freeman, 1995). The set of organizations, institutions, knowledge, interactions, and learning make up an innovation system and this system can be analysed at a lower level as a sectorial innovation system. Types of activities, actors, and products; and how these are interconnected determines the sector.

Geographical factors define national and regional innovation systems, whereas sectorial and technological innovation systems are defined by the knowledgebase that supports a particular sector or technology (Carlsson, 2016). In the sectoral system of innovation, innovative activities within a particular sector, a set of new and established products and the set of agents involved in the creation, production and sale of those products are examined. SSI surpasses specific technological and geographical boundaries, with sectors being positioned sometimes in small regional clusters, yet sometimes covering global networks, as, for example, within multinational corporations (Stenzel, 2007).

In recent years, advances in innovation theory have gradually moved closer to a fully systemic, dynamic, and non-linear process that involves a range of interacting actors. This process emphasises the significance of knowledge flows between actors; expectations about future technology, market, and policy developments; political and regulatory risk; and the institutional structures that affect incentives and barriers. Thus, while conceptual and methodological specifics vary, these more recent innovation systems emphasise the role of multiple agencies and distributed learning mechanisms in technological change. Rather than all-powerful firms or unidirectional knowledge flows, the focus is on inter-organizational networks and feedback (Winskel and Moran, 2008). The system perspectives still acknowledge the existence of stages of technology development, but they attempt to put these in a broader context.

There are various channels of university-industry interactions that facilitate innovation development. Joseph and Vinoj (2009) provide empirical evidence that in spite of the low level of university-industry interactions in the country, firms that collaborate with universities achieve a high level of innovative activities.

In particular, the role of institutions at all levels in establishing and maintaining the “rules of the game” is a central theme since institutions may constrain choices, driving innovation along certain - possibly suboptimal - paths while often throwing up barriers to more radical change (Foxon, 2003). The importance of feedback between different parts of the system – both positive and negative - is also emphasised, as are the links between technological and institutional change. A well-functioning system vastly improves the chances for a technology to be developed and diffused (Negro et al., 2008; Shekar, K. C., & Paily, G., 2019; Shekar, K. C., & Joseph, K. J., 2022).

Hence, the guiding principle of innovation studies is that if we can discover what activities and contexts foster or hamper innovation (i.e., how innovation systems function) we will be able to intentionally shape the innovation processes (Hekkert et al., 2007).

2.2 Sectorial System of Innovation (SSI) Approach

The notion of sectorial system draws from evolutionary theory, the innovation system approach and the analysis of the dynamics and transformation of industries. According to the SSI approach, a sector is seen as a set of activities which are associated with broad product groups, are addressed to an existing or emerging demand, share a common knowledgebase, and are affected by a system of actors and institutions (Malerba, 2002). Malerba (2002) defines SSI as a “set of products and the set of agents carrying out market and non-market interactions for the creation, production, and sale of those products”. SSI focuses then on the sector rather than on any geography. A sectorial systems framework focuses on three main dimensions (for a broader discussion see Malerba, 2004 and Malerba and Adams, 2019) that are typically distinguished as: a) knowledge and technological domains; b) actors and networks; and c) institutions (Malerba and Adams, 2019).

a. **Knowledge and technological domains**. A sector is characterised by a specific knowledgebase and technologies. Knowledge plays a central role in the sectorial systems approach. Knowledge is highly idiosyncratic at the firm level, does not diffuse automatically and freely among firms (Nelson and Winter, 1982), and must be absorbed by firms through the capabilities which they have accumulated over time (Cohen and Levinthal, 1990). Knowledge - especially technological knowledge- involves varying degrees of specificity, tacitness, complexity, complementarity, and independence (Winter 1987; Cowan, David, Foray 2000; Dosi and Nelson, 2010). From a dynamic perspective, it is essential to understand how knowledge and technology are created, how they are distributed and exchanged between firms, and how such processes can redefine industry boundaries.

b. **Institutions**. The cognitive frameworks, actions and interactions of agents are influenced by institutions, which include norms, common habits, established practices, rules, laws, and standards. Institutions may be binding and more or less formal (such as patent laws or specific regulations versus traditions and conventions). Many institutions have national dimensions (such as patent laws or regulations concerning the environment), while others are specific to sectors (such as standards) and may cut across national boundaries (such as international conventions or established practices).

c. **Actors and networks**. A sector is composed of heterogeneous agents that include firms (e.g., innovating and producing firms, suppliers and users), non-firm organizations (e.g., universities, financial organizations, industry associations) and individuals (e.g., consumers, entrepreneurs, professionals and scientists). These heterogeneous agents are characterised by specific learning processes, competencies, beliefs, objectives and behaviour. They interact through processes of communication, exchange, competition, control, and cooperation. Thus, in a sectorial systems framework, innovation is a process that involves systematic interactions among a wide variety of actors for the generation and exchange of knowledge relevant to innovation and its commercialisation. Actors are individuals and/or organizations that “interact through processes of communication, exchange, cooperation, competition, and governance, and various institutions shape their interactions (norms, common habits, established practices, rules, laws, standards, etc.)” (Malerba, 2002). Under this framework, many actors generate, and exchange knowledge related to innovation and its commercialisation. The sectorial innovation system undergoes changes and transformations through a co-evolution of its various elements (Nevzorova, 2021).

There are several limitations of the SSI approach. Firstly, interactions between various agents in the SSI are shaped by institutions at both sectoral and national levels. Therefore, delineating between national and sectoral boundaries is not easy. Furthermore, distinguishing the characteristics of these institutions (norms, routines, common habits, established practices, rules, laws, standards) at both levels is a challenge. Second, SSIs are also influenced by institutions at a global level. In some cases, the relevant geographical boundaries are global as well as sectoral and in such cases it is not easy to distinguish the boundary between them. Thirdly, the relationship between national institutions and sectoral systems could differ. That is, the same institution may play different roles in different countries, and thus may affect the same sectoral system differently in different countries. Finally, the nature of relationships and networks differ across sectoral systems and therefore it can be difficult and complex to compare them to each other (Baskaran, and Muchie, 2019).

No withstanding this, each of these components of a sectorial system has its own characteristics and its own set of dynamics which are important to disentangle to understand how innovation takes place. But each of these elements is also part of a broader system in which the interaction among the parts drives innovation and change.

Sectorial systems studies also expanded to the analysis of emerging and developing countries, as in Malerba and Mani (2009), Malerba and Nelson (2011), Luz and Salles-Filho (2011) and Muchie and Baskaran (2017), in which the cases of several sectorial systems in Asia, Latin America and Africa are examined. More recently catch-up by emerging and new leading countries in different sectorial systems has been examined by Lee and Malerba (2017 and 2020) and has been associated with opening of windows of opportunities and responses by firms and sectorial systems in catching-up countries and incumbent countries (see in this respect Giachetti and Marchi 2017, Morrison and Rabellotti 2017, Kang and Song 2017 and Lee and Ki 2017). The sectorial systems framework has also been adopted to examine China's catching-up in a variety of "green sectors" (Lema et al., 2020), such as solar photovoltaics (Binz et al., 2020), wind energy (Dai et al., 2020), biomass (Hansen & Hansen, 2020), and hydro energy (Zhou et al., 2020). In these sectors, the windows of opportunity for latecomers are primarily driven by institutional changes that favour clean and renewable energy and by demand conditions (Lema et al., 2020).

The existing literature (e.g., Bhagavan, 1985; Desai, 1985; Prameswaran, 2004) on India's manufacturing sector deal with Science, Technology and Innovation (STI) aspects of innovation strategies such as research and development activities and creating access to explicit codified knowledge, and technical efficiency, etc. The innovation system combining a strong version of the STI mode with a Doing, Using and Interacting (DUI) mode can provide a better picture of innovative behavior of the firms (Jenson et al., 2007; Shekar, K. C., & Joseph, K. J., 2022).

2.3 System failure

As previously highlighted, the basic conceptual underpinnings of the SI approach are, first, that innovation does not take place in isolation and interaction is central to the process; second, that institutions are crucial to economic behavior and performance (Smith, 1996); and third, that evolutionary processes play an important role, they generate variety, select across that variety, and produce feedback from the selection process to variation creation (Hauknes and Nordgren, 1999).

In all these basic elements, systemic imperfections can occur if the combination of mechanisms is not functioning efficiently. This can translate into various types of system failure:

- Infrastructure failure, where there is a lack of formal institutions/institutional mechanisms as well as soft institutions, social norms, trust, values that hinder innovation.
- Institutional failure, where there is lack of networking/linkages among the different actors in the whole ecosystem.
- Network failure/Capability failure, which underscores the absence of the necessary capabilities of the actors to move up the value chain, adapt to new and changing circumstances etc.
- Directionality failure, where there is a lack of shared vision, collective coordination, regulation, targeted funding regarding the goal and direction of the transformation process.
- Demand articulation failure, caused by improper anticipation and learning about user needs, shaping innovation based on user needs, lack of instruments for supporting user-led and open innovation, novel innovations/solutions not finding enough space in public procurement.

- Policy coordination failure, due to a lack of multi-level policy coordination, horizontal and vertical coordination, across and within different systemic levels; between regional and national or between technological and sectoral systems, etc.
- Reflexivity failure, as a result of an insufficient ability of the system to monitor, anticipate and involve actors in processes of self-governance (Woolthuis, et al., 2005).

The systemic failures as presented above cannot be addressed directly, or by one actor alone. If policy makers want to use the framework, they will have to address groups of actors to make changes in the innovation system possible. Consequently, as opposed to the market failure approach for driving policy, a systems approach to innovation is seen as more robust (Bergek et al., 2010).

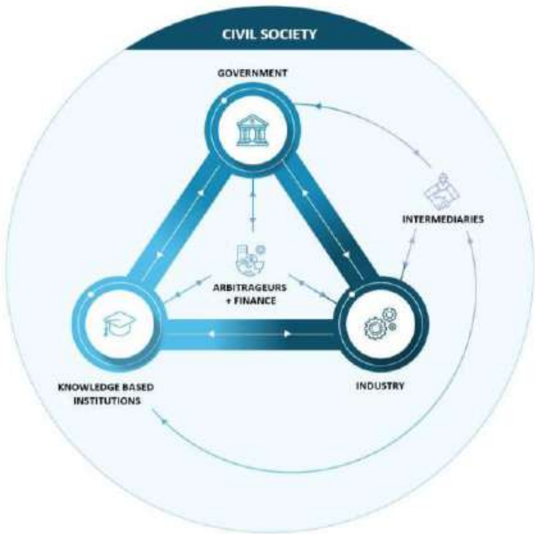
By using the systems framework as a tool for analysis, policy makers can identify: (1) where systemic failures occur; and (2) which actors should be addressed to make change possible. Most problems in the innovation system will not be uni-dimensional but will consist of a complex mixture of causes and effects and involve several actors. By using the framework, priorities can be given to the most stringent obstacles for innovation and thus also serve as a guideline to implement innovation policy.

2.4 The Triple Helix (TH) Model

Besides the systems approach, there are other tools that have the potential to offer similar facilitation for innovation at the sectorial level. The Triple Helix Model is advocated to be a powerful tool for linking universities to the rest. This can also be seen as a tool for operationalising the IS concept. However, this might require setting-up a proper framework at a low scale to set the foundation for the running of the system, which is expected to be inclusive and socially embedded in the context of developing countries.

This interaction between government, universities and firms is addressed in the "Triple Helix" Model proposed by Etzkowitz and Leydesdorff (1997). This model is a descriptive construct of the components, interaction channels and functions or benefits of an effective NIS (Ranga and Etzkowitz, 2013; Santana, 2016).

FIGURE 2: Triple Helix Model extension



Etzkowitz (2002) states that interaction channels are necessary when firms and government are related with universities in knowledge-based economies. From a business perspective, the most important channels of transfer of knowledge are: open science, property rights, human resources, projects of collaborative research and development (R&D) and networking among actors (Cohen et al., 2002; Hanel & St.-Pierre, 2006; Arza, 2010; Bekkers & Freitas, 2008; Ruiz, Corrales and Orozco, 2017).

The triple helix is effective in understanding the dynamics of innovation at the sectorial, regional, national or international level, as it provides a well-elaborated framework for understanding central inquiries in innovation processes, including a) What the key actors are and b) What the mechanisms of interactions are (Cai and Amaral, 2021). Traditionally, the literature on the Triple Helix Model has focused on the relationships between universities and knowledge-based institutions (KBIs), firms, governments, and hybrid organizations at the intersection of these three helices (Etzkowitz and Leydesdorff, 1995; Leydesdorff, 2001). Etzkowitz and Leydesdorff developed the Triple Helix Model to explain the dynamic interactions between academia, industry, and government that foster entrepreneurship, innovation, and economic growth in a knowledge-based economy (Etzkowitz & Leydesdorff, 2000).

According to the literature, the scope and intensity of the interactions between the three actors are reflected in varying institutional arrangements, referred to as Triple Helix Type I, II, and III (TH-Type I, II and III) (Etzkowitz and Leydesdorff, 2000; Etzkowitz, 2003, 2008; Ranga and Etzkowitz, 2013).

In the TH- Type I, the three helices are strongly defined, with relatively weak interactions. Institutionally, "the nation state encompasses academia and industry and directs the relations between them" (Etzkowitz and Leydesdorff, 2000: p. 111). New knowledge is produced only within universities and research centres. Hence, TH-Type I is largely viewed as a failed development model with not enough room for 'bottom up' initiatives, where "innovation was discouraged rather than encouraged" (Etzkowitz and Leydesdorff, 2000, pg.112). To achieve statist reform "the first step […] is the loosening of top-down control and the creation of civil society where one is lacking" (Etzkowitz, 2003a, pg.304). Otherwise, there is minimal direct connection to the needs of society, which in turn discourages the introduction and diffusion of innovations in the economy (Martin and Etzkowitz, 2000).

Triple Helix Type II is characterised by decreasing direct control of the state on the functions of Type I with a shift of focus on fixing market failures. The mechanisms of communication between the actors are strongly influenced by and deeply grounded in market mechanisms and innovations (Nelson and Winter, 1982; Bartels, et al., 2012). The point of control is at the interfaces (Leydesdorff, 1997) and consequently, new codes of communication are developed (Leydesdorff and Etzkowitz, 1998b). Research is also carried out outside universities and research centres. As research becomes increasingly multidisciplinary and applied, societal needs have a direct influence on it (Etzkowitz and Leydesdorff, 2000; Martin and Etzkowitz, 2000; Ranga and Etzkowitz, 2013).

TH-Type II can be considered a 'laissez-faire' model of interaction "in which people are expected to act competitively rather than cooperatively in their relations with each other" (Etzkowitz, 2003, pg.305). To summarise and compare TH-Types I and II, "statist societies emphasise the coordinating role of government while laissez-faire societies focus on the productive force of industry as the prime mover of economic and social development" (Etzkowitz, 2008, pg.13).

However, in TH-Type III, the three actors assume each other's roles in the institutional spheres as well as the performance of their traditional functions. With the emergence of TH-Type III, a complex network of organizational ties has developed, both formal and informal, among the overlapping spheres of operations. The transformation of universities is of particular relevance. After having incorporated research as an additional mission beyond teaching, universities recognise their role in the pursuit of economic and social development (Etzkowitz and Leydesdorff, 2000; Webster, 2000; Ranga and Etzkowitz, 2013; Etzkowitz, 2008, 2017). Hence, universities take on entrepreneurial tasks such as marketing knowledge, increased technology transfers and the creation of spin-offs and startups, as a result of both internal and external influences (Etzkowitz, 2017; Etzkowitz and Leydesdorff, 2000; Etzkowitz et al., 2000). These entrepreneurial activities are assumed with regional and national objectives in mind, as well as financial improvements to the university and the faculty (Etzkowitz, et al., 2000). In doing so, universities cease to be ivory towers, disconnected and isolated from society, but interact closely with industry and government (Etzkowitz and Leydesdorff, 2000; Etzkowitz et al., 2000). In addition to the above, "firms develop an academic dimension, sharing knowledge among each other and training employees at ever higher skill levels" (Leydesdorff and Etzkowitz, 1998, pg.98), as well as increasing collaboration with knowledge-based institutions (KBIs). Improved university-industry collaboration is visualised through: i) an increased patenting output, particularly as they are a "repository of information about how the socially organised production of scientific knowledge is interfaced with the economy" (Leydesdorff, 2004); ii) the increase in university revenues from licensing (Perkmann and Walsh, 2007); iii) a greater proportion of industry funds making up university income (Hall, 2004); and iv) the diffusion of technology transfer offices, industry collaboration support offices and science parks (Siegel et al., 2003, in Perkmann and Walsh, 2007, pg. 4). Governments therefore create incentives through "informed trade-offs between investments in industrial policies, S&T policies, and/or delicate and balanced interventions at the structural level" (Leydesdorff, 2005). Phrased differently, there is a shift in the traditional role of policy from the facilitation of basic science to its 'bridging function'. In a nutshell, the Triple Helix Type III assumes that the three spheres - universities, industry, and government - overlap, and their boundaries become more permeable. A complex network of organizational ties develops individuals and ideas move around the three helices, and synergies are maximised (Etzkowitz, 2002). Actors evolve and assume each other's roles, with new hybrid organizations emerging at the interfaces, for example incubators, accelerators, science parks, technology transfer offices, venture capital firms, angel networks, and seed capital funds (Etzkowitz, 2000; Etzkowitz and Leydesdorff, 2000; Etzkowitz, 2002; Ranga and Etzkowitz, 2013).

The Triple Helix Model has also been applied to the context of developing economies. Case studies document how innovation and learning processes differ in developing economies, what factors constrain the adoption of more integrated Triple Helix models, and how actors and mechanisms cope with these factors (Sarpong et al., 2017). In this regard, it has been noted that while the components of the triple helix do not change, the intensity and quality of their interactions are often weaker than in developed economies (Dzisah and Etzkowitz, 2008). Generally, in order to address such challenges effectively, through tailored and targeted policy interventions, there is the clear need for system level measurement.

2.5 Towards an Analytical Framework

The framework for analysis of the IICTSSI is grounded in the literature, but it extends the traditional model in two main ways and is referred to as Triple Helix (TH-Type IV) Type IV[16, 17]. The TH-Type IV has the additional features of arbitrageurs (banks, financial institutions, venture capital and angel investors) and intermediary organizations (industry associations, institutions supporting technical change and incubators), as well as diffused ICT in the context of the fourth industrial revolution.

Arbitrageurs can be defined as venture capitalists, angel investors/ networks and knowledge brokers. They are essential for the innovation process as it requires internal and external knowledge for the development of new ideas, business models and types of companies. As such, knowledge brokers and venture capitalists fulfil this requirement through the provision of links, knowledge sources and even technical knowledge so that firms can improve their performance in terms of survival rate as well as accelerate and increase the effectiveness of their innovation processes (Zook, 2003; Baygan and Freudenberg, 2000). Their resource allocation role is based on the assessment of advantages in information asymmetries (Williamson, 1969, 1971, 1973) (Bartels, et al., 2012, pg.7). However, information asymmetry and uncertainty can lead to transaction problems. “Countries seeking to encourage the emergence and growth of entrepreneurial firms need to devise ways that reduce transaction problems” (Li and Zahra, 2012, pg.95). It can be said that a combination of both formal institutions and (informal) cultural values can provide the proper incentives to reduce transaction problems. Arbitrageurs are therefore of vital importance as the innovation process requires internal and external intermediation (financial, knowledge, transacting and investment), and as such, complement the traditional Triple Helix Model.

Intermediaries are recognised as actors that place themselves in the middle of relationships between other actors, or actors that facilitate the process of interacting in exchange relationships. Four roles of intermediaries include: (a) consultant, providing information and advice in the recognition, acquisition and utilisation of the relevant intellectual property and technological capabilities; (b) broker, brokering a transaction between two or more parties; (c) mediator, acting as an independent third party who assists two organizations achieve a mutually beneficial collaboration and (d) resource provider, acting as an agent who secures access to funding and other material support for the innovation outcomes of such collaborations (Chunhavuthiyanon & Intarakumnerd, 2014; Chappin et al, 2008).

Nakwa et al., (2012) highlight the importance of intermediaries in transforming pre-existing inter-firm networks into more robust, dynamic, and sustainable system-oriented networks. In addition, Nakwa et al., (2012) indicate that “intermediaries play a sponsoring role at the policy level by channeling resources to industry; a brokering role at the strategic level by linking triple helix actors; and a boundary spanning role at the operational level by providing services that facilitate knowledge circulation”.

Intermediary organizations are pertinent in facilitating the flow of knowledge, technology, and skills among the actors of the SI. Within this actor group, institutions supporting technical change (ISTC) promote knowledge generation, technology development and commercialisation; facilitators like industry associations establish and reinforce the links between system actors through networking; enablers such as industrial parks and incubators support with infrastructure, framework conditions, capabilities and related resources and funders (Letaba, 2019).

Table 2 below shows core actors, arbitrageurs and intermediary organizations by the function they perform in the Indian ICT sector. These functions span across the innovation value chain, namely: knowledge generation and transfer; technology development, acquisition, and transfer; product development; testing service; commercialisation; and business development.

[16] Leydesdorff claims no ex-ante or necessary limitation to three helices for the explanation of complex developments, but instead proposes that an N-tuple or an alphabet of (20+) helices can be envisioned. However, in scholarly discourse and for methodological reasons, one may wish to extend models step by step and as needed to gain explanatory power. (Leydesdorff, 2012).

[17] Civil society - comprising the activities of non-state organizations, institutions and movements - has in recent years emerged as the major force for change in the realms of politics, public policy and society both globally and locally. It is also recognized as an actor in the quadruple helix (Roman et al., 2020). Yet, despite the crucial importance of this political phenomenon to the principle and practice of democracy, it eludes definition and systematic understanding (Anheier 2004). The benefits of incorporating civil society within systems measurement, and hence policy craft include: i) the provision of bottom-up insights, particularly as civil society represents demand-side perspectives, such as innovation users and consumers; ii) supports the creation of social innovations, and legitimation and justification for innovations; iii) promotes commitment to and ownership of a development agenda. However, despite the aforementioned benefits civil society comprises a heterogeneous group of actors who must themselves be approached differently and therefore measurement is a challenge. It would be important to note that participation of civil society should be included for the policy selection and implementation process.

TABLE 2: Intermediary organizations by function in the ICT sector

Function	Knowledge based institutions	Government	Intermediaries	Arbitrageurs (VCs, Angel Investors, NBFCs)
Technology Development	• IIT's • NIT's • IIIT's • NIELIT	• National Informatics Centre (NIC) • MEITY	• MAIT • NASSCOM	
Technology Transfer	• Science Park • University-enterprise joint research centre • University-owned enterprise centre	• MEITY	• TIFAC • NASSCOM • T-Hub	
Technology Acquisition	-			
R&D	• Centre for Development of Advanced Computing (C-DAC) • Centre for Development of Imaging Technology (C-DIT)	• Society for Applied Microwave Electronics Engineering & Research (SAMEER)	• NASSCOM	
Knowledge Transfer	• National Telecommunications Institute for Policy Research, Innovations & Training (NITPRIT)	• MEITY • Ministry of Education	• Geospatial Information and Technology Association (GITA) • Internet and Mobile Association of India (IAMAI) • Association of Competitive Telecom Operators (ACTO) • India Electronics & Semiconductor Association (IESA)	• Eagle Ventures • Indian Angel Network (IAN) • Kalaari Capital • Indian Academy of Venture Capital (IAVC)
IP Protection	-	• Copyright Office	• Data Security Council of India (DSCI)	
Infrastructure Development	• Electropreneur Park at Delhi University	• Software Technology Parks (STP)	• IKP Knowledge Park	
Product Development		• Software Technology Parks (STP)		
Human Capital Development	• IIT's • NIT's • IIIT's • NIELIT	-	• STPI Virtual & Augmented Centre of Entrepreneurship (VARCoE)	• State Bank Institute of Innovation & Technology (SBIIT)
Business Development	• STPI IoT OpenLabCoE • STPI FINBLUE • STPI NEURON • STPI MOTION • STPI Apiary	• Electronic and Computer Software Export Promotion Council (ESC) • Software Technology Parks (STP)	• NASSCOM CoE IoT • NASSCOM CoE DSAI • KSUM • K-TECH Innovation Hub	
Funding	• University-enterprise joint research centre	• Ministry of Education • Ministry of Electronics & Information Technology	• KSUM • IKP Knowledge Park	• ICICI Bank • HDFC Bank • SBI Startup Bank
Fundraising	-	-	-	
Agenda Setting	• Ministry of Education	• Ministry of Electronics & Information Technology	• NASSCOM	
Testing & Certification Services	• University-enterprise joint research centre • Kohli Center on Intelligent Systems (KCIS)	• Semi-Conductor Laboratory (SCL) • Telecommunications Standards Development Society, India (TSDS) • National Accreditation Board for Testing and Calibration Laboratories (NABL) • Standardisation Testing and Quality Certification Directorate (STQC)	• National Cyber Safety and Security Standards	

Source: Letaba, Petrus (2019)

Compared to the Triple Helix Type III, our augmented version of the model also gives prominence to the fourth industrial revolution (4IR) and digital transformation through ICTs. Through the spread of digital information and ICT, a new technological wave and a new corresponding mode of development has emerged (Perez, 1983; Freeman and Louça, 2001; Mowery, 2009). Innovation activities shape and use ICTs with lagged but often large effects on productivity and innovation in both developed and developing economies (Paunov and Rollo, 2016; Hjort and Poulsen, 2017). The channels through which ICTs affect firms' productivity and innovation are multiple, and often difficult to disentangle. For example, ICTs can facilitate access to information and knowledge, fostering learning and knowledge flows, or ease communication among firms and SSI actors, thereby promoting collaborative projects. To make the most of these new technologies, countries have put in place several policies. However, often their design does not take full account of the local environment in which actors operate, suggesting a potentially large role for evidence-based policymaking in this area (Koria et al., 2014).

Today, ICTs are at the center of what many believe to be the Fourth Industrial Revolution (4IR) (World Bank, 2016). Each of the actors in the Triple Helix Type IV has a specific role to play in the context of the 4IR. Using analytics and data, the 4IR allows firms to identify new opportunities, expand their businesses and tap into new markets. 4IR technologies enable firms to increase their productivity, provide better customer experience, and optimise resources.

Universities have a great role to play to make the 4IR a reality, particularly through fostering the development of future skills as well as acting as test beds for new technologies. The role of the government in the context of the 4IR is to facilitate the adoption of emerging technologies through support infrastructure and regulations (Kucirkova, 2019).

The adoption of the 4IR and digital transformation requires investments which could be satisfied with the help of arbitrageurs such as venture capital (Deloitte, 2018a). Innovative technologies are becoming more prevalent and venture capitalists are making even greater investments in them. Venture capital investments in 4IR-focused startups have steadily increased, both in terms of size and number of deals. Globally, venture capital investments in this arena grew from approximately US$ 600 million in 2014 to US$ 2.3 billion in 2016, representing a 40% CAGR (Deloitte, 2018).

However, venture capitalists need to be mindful of conservative and risk-averse investment strategies that fail to consider a broad range of promising investments bias towards companies in specific narrowly defined industries. VCs should not conflate “risk averse” with prudent (Forbes, 2021). Regular communication between arbitrageurs and especially with industry and other actors such as KBIs, government and intermediaries can help VCs understand the dynamics of the sector and invest accordingly.

Due to the rapid changes in technologies linked to digital transformation and the 4IR, firms require the support of intermediaries as knowledge brokers. Intermediaries can ensure that knowledge spillover processes are more inclusive for firms and thereby contribute to developing their absorptive capacities. In addition, intermediaries have a vital role in building efficient technology transfer systems between actors of the system of innovation (Karlsen et al, 2022).

In light of the above, utilising the Triple Helix Type IV for measuring the ICT Sectorial System of Innovation (IICTSSI) provides an evidence-based framework for identifying barriers and priorities, leading to the articulation of policies and targeted short, medium and long-term interventions.

3.

Survey Methodology

Survey Methodology

The Indian Information and Communication Technology Sectorial System of Innovation (IICTSSI) Survey has been conducted to obtain a holistic view of the SSI as a basis for evidence-based innovation policy for the ICT sector. The ICT sector is one out of the five sectors surveyed under the sectorial system of innovation component of the National Manufacturing Innovation Survey 2021-22.

Essentially, two basic forms of data collection exist, those with and those without an interviewer, or, phrased differently: interviews and self-administered questionnaires (De Leeuw, 2009 in Dillman ed). Interview surveys can either be administered in person or over the telephone. There is a great deal of variation in the use of these methods across countries, due to technical reasons, lack of infrastructure, or cultural norms (Dillman, 1978; Dillman, 1998). Self-administered questionnaires take on many forms and can be used in group or individual settings. A well-known example of a self-administered questionnaire is the mail survey, and its computerized equivalent, the Internet survey, which is the current norm (Raziano, et al., 2001; De Leeuw et al., 2003). Often a combination approach is used, particularly when there is the need to ask sensitive questions. All the taxonomical approaches mentioned are respondent orientated, and the method choice is complex and based on a delicate balance between the quality of the data acquired, time and costs.

The Internet-based approach was chosen in line with the reasoning of Koria, et al., (2012), that i) "... maximising the use of the budget, internet surveys can cover a much larger sample size than the conventional mail survey (Berrens, et al., 2003); ii) the time dimension associated with conducting web-based surveys is much lower in comparison to other forms (Cobanoglu et al., 2001); iii) the quality of retrieved data is higher in terms of non-response and the ability to include conditionality in a discreet manner (Olsen, 2009); iv) a higher reliability of data is achieved due to the reduced need for data entry (Ballantyne, 2004; and Muffo, et al., 2003)" (Koria, et al., 2012., pg.8); and v) the emergence of the COVID-19 pandemic restrictions during the implementation phase of the project which limited face-to face interaction.

3.1 Sample Selection

As per the "Theoretical Framework" chapter, the IICTSSI Survey focuses on five core actor groups, namely: government (GOV), knowledge-based institutions (KBI); arbitrageurs (ARB); intermediaries (INT) and industry (IND). The executive policy community, essentially the government (GOV), is represented by high-level officials (national and state level) in the relevant public institutions that are directly or indirectly responsible for innovation in the ICT sector. Knowledge-based institutions (KBIs) are represented by the heads of university faculties/ departments from the disciplines of engineering, technology and innovation, think-tanks, as well as both public and private research institutes (RIs). Arbitrageurs (ARB) comprise the venture capital, angel investors, and banks or other financial institutions and are represented by their respective heads or senior management. Intermediaries constitute industry associations and institutions supporting technical change such as regulatory bodies and are represented at the managerial level. The industrial community is represented by the CEOs of firms from the ICT sector.

Procedure:

Non-firm actors, namely GOV, KBI, ARB and INT were sampled on a convenience basis. A frame was prepared for the ICT sector with around 200 relevant non-firm actors within GOV (20), KBI (50), ARB (50) and INT (80) which was treated as the universe and the sample. Sampling for firms (IND) were conducted through stratified random sampling across 28 states and 8 union territories, the five sectors, including the textiles and apparel sectors from the National Industrial Classification (NIC) 13 and 14 (2008) and their respective firm sizes measured through a combination of turnover, investment in plant and machinery or equipment or employment.

The sampling frame for firm actors has been obtained from the "Annual Survey of Industries" (ASI) 2018-19 frame, the Centre for Monitoring Indian Economy's (CMIE) Prowess IQ database (2018-19) and the Department of Science and Technology's (DST) directory (2018-19). With a total of 28,394 firms from the textiles and apparel sector, after sampling 2,085 firms were to be surveyed. The target population is broken down into similarly structured subgroups or strata, which are as homogeneous as possible, and form mutually exclusive groups. Appropriate stratification will normally give results with smaller sampling errors than a non-stratified sample of the same size and will make it possible to ensure that there are enough units in the respective domains to produce results of acceptable quality. Wherever possible, turnover and investment in plant and machinery or equipment[18,19], as per the 2020 MSME definition are used to calculate firm size as listed below.

[18] The expression "plant and machinery or equipment" of the enterprise, shall have the same meaning as assigned to the plant and machinery in the Income Tax Rules, 1962 framed under the Income Tax Act, 1961 and shall include all tangible assets (other than land and building, furniture and fittings): https://msme.gov.in/sites/default/files/IndianGazzate_0.pdf

[19] Data on turnover and investment in plant and machinery or equipment is inflation-adjusted using CPI with base year 2015. Investment in plant and machinery or equipment values are adjusted for depreciation by taking their net values.

FIGURE: Firm size classification

Turnover	≤ 5 cr	Large	Medium	Small	Micro
Turnover	≤ 50 cr	Large	Medium	Small	Small
Turnover	≤ 250 cr	Large	Medium	Medium	Medium
Turnover	> 250 cr	Large	Large	Large	Large
Firm size classification		> 50 cr	≤ 50 cr	≤ 10 cr	≤ 1 cr
		Investment in plant and machinery or equipment			

The Government of India notification mentions that: If an enterprise crosses the ceiling limits specified for its present category in either of the two criteria of investment or turnover, it will cease to exist in that category and be placed in the next higher category but no enterprise shall be placed in the lower category unless it goes below the ceiling limits specified for its present category in both the criteria of investment as well as turnover.

In some cases, employment data was used as a proxy for firm size and the firms were reclassified post the survey.

- Large – 200 + employees (Kapoor., 2016, p.11)[20]
- Medium – 50 to 199 employees
- Small – 20 to 49 employees
- Micro – 0 to 19 employees (Kapoor., 2018, p.12)

Limitations:

- The data collection was impacted due to the covid crisis as businesses were closed. This has affected the survey response rate to some extent with an overall response rate of 78.55%, a firm response rate of 39.04% and non-firm response rate of 115.50%.
- Absence of a baseline for evaluating the performance of SSIs in India as there are no prior surveys conducted along the same lines.
- The classification of firms into large, medium, small and micro is only a rough estimate given that the universe is a combination of 3 databases with the absence of similar parameters to measure firm size.

3.2 Data Collection

Due to the technical nature of the data to be collected it is imperative that the quality and integrity of information is ensured. Consequently, the outlined approach was utilised to maintain a level of rigour in the selection of enumerators from the Indian knowledge-based and technical institutions, as compared to standard data collection firms. The merits of the approach are outlined below:

Selection of enumerators and retention

Criteria: Given the highly technical nature of the information collected it is imperative that the selected enumerators were able to:

- Comprehend the specifics of innovation and systems of innovation.
- Effectively communicate innovation constructs to the target respondent.
- Guide the discussion as and when required, based on some degree of understanding and exposure to innovation in the sector, which will also enable them to support data analysis and reporting.
- Demonstrate experience in data collection and therefore be able to extract nuanced information.
- Communicate in the relevant regional language of the focus state; and
- Summarise the findings and participate in further analysis of the data to support the UNIDO team.

Enumerators were trained on systems of innovation, technical aspects related to the ICT sector and data collection techniques with the Lime Survey® interface. In order to ensure data quality, Lime Survey® enables real time tracking of enumerators to the respondent level through the back end. It also signals when surveys have been partially completed. The fact that an online interface is being used means that there is zero transcription error, that is, once the response to a question is given it is

[20] Small firms are defined as those having less than 50 employees, medium firms have 50-199 employees and large firms are defined as those having 200 or more workers.

automatically updated to the database. In addition, spot checks from the response data are randomly taken to ensure data quality at the level of each individual enumerator is being maintained.

3.3 The Data Acquisition Survey Instrument (DASI)

The Data Acquisition Survey Instrument (DASI) for the IICTSSI Survey was created using an interative multi-step process, and currently stands at its fourth iteration. The provenance of the earlier iterations of the tool can be found in the Ghana, Kenya and Cabo Verde National System of Innovation Survey Reports (Bartels and Koria, 2012, 2015; Koria, 2019). The current iteration, DASI-V4, saw the introduction of new actor-specific questions to support measurement at the sectorial level and to provide better insights at the actor level. This enhancement of the DASI allows for greater accuracy and impact of the policy recommendations in the short-, medium-, and long-term.

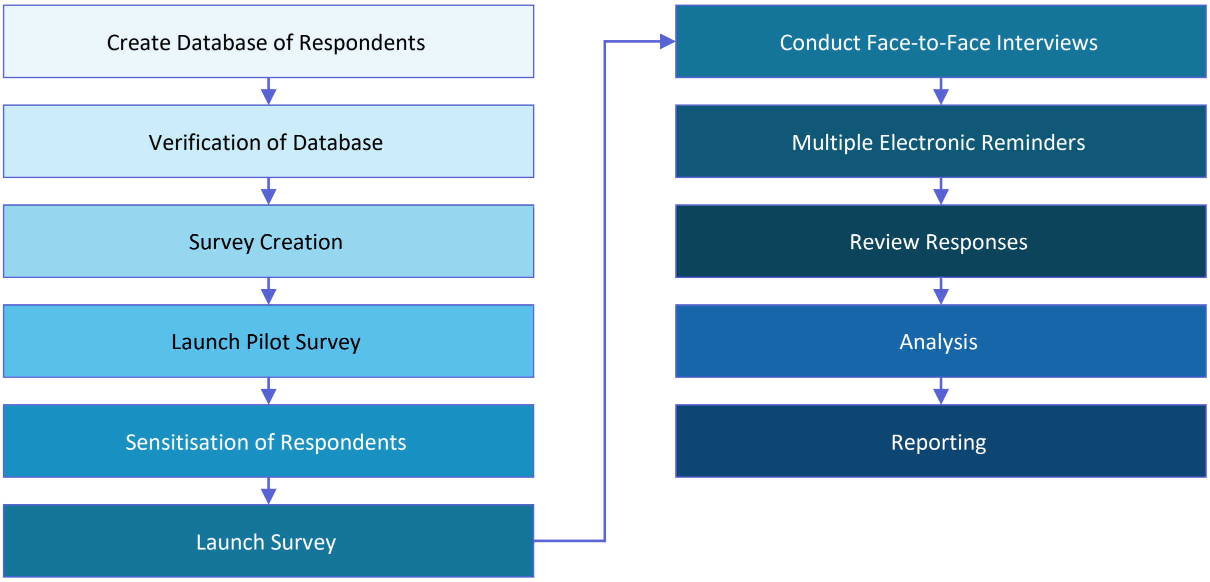
3.4 Survey Operationalisation

The launch of the survey was accomplished by using a combination of both the free open-source software tool Lime Survey® as well as, where possible, face-to-face interviews. The Lime Survey® tool is an advanced online survey system. The outputs from the verification protocol were uploaded into the Lime Survey® system and individual tokens were assigned to each target respondent. This restricted survey access solely to the targeted qualified individual respondent, therefore greatly enhancing the fidelity, reliability and validity of the results obtained.

As previously mentioned, the IICTSSI Survey was launched remotely once the initial critical mass of target respondent contacts had been gathered. The survey was remotely and non-intrusively managed via the Lime Survey® interface. Electronic reminders were sent out to the target respondents who had only partially completed or not responded at all. This process was facilitated by the structure of the Lime Survey® back-end, as the system logs the exact date and time at which the survey was accessed and to what degree it was completed.

For those who had not accessed the survey for a long period, a follow up was made telephonically to monitor any potential technical difficulties. Once responses were completed, they were automatically uploaded into the survey response database. On completion of data collection, the survey responses were analysed with the planned statistical analysis in mind. Figure 3 shows the steps associated with the data collection process.

FIGURE 3: Operational Methodology



3.5 Secondary Data Collection

In addition to the primary data collection undertaken, it is crucial to gain a view of what is being presented in the form of secondary sources at the sectorial level, particularly those from the government. The secondary sources that were analysed comprised qualitative material consisting of policy documents, government budget statements, development strategies and action plans at the national and sectorial levels. The purpose of analysing these documents was to gain an understanding of the policy direction that the Government of India is taking with respect to innovation in the ICT sector. Phrased differently, is there convergence or divergence between what is presented within policy documentation from the actual results obtained? The results of the analysis are presented in the “Results and Analysis” chapter of this report.

3.6 Stakeholder consultation

In order to garner preliminary insights into the results obtained from the survey, a stakeholder consultation was undertaken. Results were presented and discussed with sector experts and practitioners in order to understand whether or not the observations were meaningful. The platform provided an opportunity to orient the report writing through linking the findings to specific case examples as well as highlighting any supporting secondary research that may have been conducted at the national level. The process was important for the identification of any potential outliers in the results.

4.

Manufacturing Landscape in the ICT Sector

Manufacturing Landscape in the ICT Sector

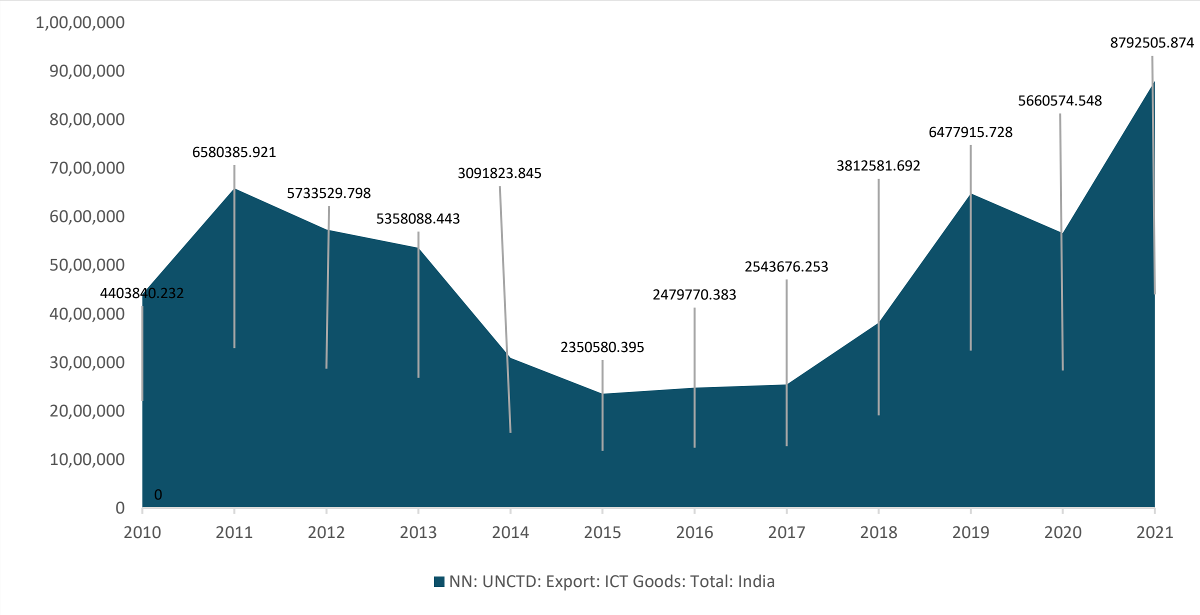
4.1 Indian Information & Communication Technology Sector: Structure and Dynamics

Information and Communications Technology (ICT) has been the sunrise sector of the economy for a very long time and India's ICT services exports have witnessed a growth story like no other sector in the last three decades. India is considered a pioneer in software development and a favoured destination for information technology-enabled services (ITeS). The software exports of the country contribute 7.4% to the gross domestic product (GDP), marginally down by 0.6% from the last financial year (FY) (Invest India and IBEF, 2022) and the ICT industry contributes 13%. India aims to grow the sector to US$ 1 trillion by 2025 or up to 20% of the GDP (International Trade Administration Country Guides, United States[21]). The industry has a 51% share in the global outsourcing market and contributes 51% of India's total services exports (Khurana, 2021). Revenue has been growing at a rate of 8.1% and close to half a million employees were added in 2022 alone with a total of 5 million people in direct employment in the industry and another 7 million in indirect employment. By value, in the FY 2021-22, the exports of software and IT services comprised the following segments: business and financial services stood at US$ 61.4 billion, high technology and telecom services at US$ 24.3 billion, manufacturing services at US$ 26.3 billion and other services at US$ 37.2 billion (NASSCOM and Ministry of Finance in the Economic Survey, 2021-22). The export of telecom equipment reached an all-time high of US$ 6652 million in the FY 2022-23 (partial data from Directorate General of Commercial Intelligence & Services; Department of Commerce) from the previous FY, 2021-22, where it was US$ 3967.94 million.

According to NASSCOM, an industry body, India's IT industry revenues have touched US$ 227 billion. In 2022 alone, the export revenue from this industry (excluding e-commerce) is estimated at close to US$ 178 billion. India imported over US$2.4 billion in computer and electronic equipment (NAICS code 334) from the United States in 2021. According to Gartner, IT spending in India will increase by 7% to US$ 101.8 billion in 2022. The computer software and hardware sectors attract the second highest foreign direct investment (FDI) inflow; Between April 2000 and March 2022 it attracted over US$ 85 billion. Up to 100% FDI is allowed in: data processing, software development and computer consultancy services; software supply services; business and management consultancy services, market research services, technical testing and analysis services, under automatic route. India's IT spending has increased to US$ 101.8 billion from US$ 81.89 billion in the FY 2020-21 (Gartner, 2022). India's share of global ICT services exports grew to 49.67% in 2021 and currently tops the list of ICT service exporters. More recently, the share of ICT services in services exports has grown from 9.3% in 2014 to 15.8% in 2021. Overall, global services exports have grown in value from US$ 5.31 trillion in 2014 to US$ 6.04 trillion in 2021 (International Monetary Fund, Balance of Payments Statistics Yearbook). India's software services exports grew at 17.2% to US$ 156.7 billion in the FY 2021-22 after touching a record high of US$ 254.4 billion. Services contribute 40% of India's exports, however, there is greater growth in service exports than in merchandise. India's global share of ICT goods exports increased to 2.1% in 2020 from 1% in 2014. The share of high technology exports in India's manufactured exports was 9% in 2014 and rose to 11% in 2020 (UN COMTRADE Database, WITS Platform). India's ICT goods exports reached an all-time high of US$ 8.9 billion in 2022 (see Figure 4 below).

[21] India - Country Commercial Guides, Official website of the International Trade Administration, United States: https://www.trade.gov/country-commercial-guides/india-information-and-communication-technology

FIGURE 4: India's ICT goods exports



Source: UNCTAD, available on: CEIC Data[22]

According to a survey of 1815 respondent firms out of 6115 software firms (with respondent firms accounting for 86.5% of total software services exports) conducted by the Reserve Bank of India in the 2020-21 round, the distribution of services exports as a snapshot and under various modes of supply is shown in Table 3 below.

TABLE 3: Survey response and final estimates for 2020-21 – A snapshot

(₹ crore)		
Item	**Reported***	**Final Estimates**
	1	**2**
No. of companies	1,815	6,115
Total Exports of Software Services	8,58,608	9,92,141
• IT services	5,38,395	6,14,678
• Software Product Development	26,958	33,230
• BPO Services	2,36,039	2,78,507
• Engineering Services	57,216	65,726
Total Exports of Software Services (including commercial presence)	9,66,639	11,00,172
• Mode 1 (cross-border supply)	7,46,650	8,62,661
• Mode 2 (consumption abroad)	1,029	1,191
• Mode 3 (commercial presence)	1,08,031	1,08,031
• Mode 4 (presence of natural person)	1,10,929	1,28,289

** Responses by the largest 20 companies ensured industry representation in the survey coverage.*

Source: Reserve Bank of India Survey on ICT, 2020-21

Table 3 above shows the dominance of IT services, business process outsourcing (BPO) and engineering services in India's software services exports. Computer services and IT enabled services (ITeS) contributed 65.3% and 34.7% of software services exports (see Table 4 below) respectively. Among the modes of supply shown in Table 3 above, Mode

[22] CEIC Database on India's ICT Goods Exports: https://www.ceicdata.com/en/indicator/india/exports-ict-goods

1 (cross- border supply), Mode 4 (presence of natural person) and Mode 3 (commercial presence) are relatively more important in India's services export profile. The issue of skilled technical personnel going to two major IT services markets, namely the United States and Europe, arises on account of the emergence of Mode 3 supply through skilled migration routes like H1B work visa and skilled worker visa programmes. However, excluding Mode 3 supply of commercial presence, India's software services exports are estimated at US$ 133.7 billion.

TABLE 4: Software services exports from India

Activity	2019-20			2020-21		
	₹ crore	US $ billion*	Share (%)	₹ crore	US $ billion*	Share (%)
	-1	-2	-3	-4	-5	-6
A. Computer Services	6,07,203	85.7	66.6	6,47,908	87.3	65.3
• IT services	5,71,712	80.7	62.7	6,14,678	82.8	62
• Software Product Development	35,491	5	3.9	33,230	4.5	3.3
B. IT Enabled Services	3,04,499	42.9	33.4	3,44,233	46.4	34.7
• BPO Services	2,36,172	33.3	25.9	2,78,507	37.5	28.1
• Engineering Services	68,327	9.6	7.5	65,726	8.9	6.6
Total Export of Software Services (A+B)	**9,11,702**	**128.6**	**100**	**9,92,141**	**133.7**	**100**

Note: The sum of components may differ from total due to rounding off.
** Using annual average Rupee/ Dollar exchange rate. These footnotes are applicable for all other tables also.*

Source: Reserve Bank of India Survey on ICT, 2020-21

BPO services comprise most of India's ITeS exports. The segment is well-differentiated in its profile of services, that are tailor-made for specific sectors. Table 5 below shows the industry-wise distribution.

TABLE 5: Industry-wise distribution of ITeS/BPO services exports

Activity	2019-20			2020-21		
	₹ Crore	US $ billion	Share (%)	₹ crore	US $ billion	Share (%)
	-1	-2	-3	-4	-5	-6
BPO Services	**2,36,172**	**33.3**	**77.6**	**2,78,507**	**37.5**	**81**
• Business consulting services including public relations services	30,646	4.3	10.1	34,510	4.6	10
• Finance and Accounting auditing bookkeeping and tax consulting services	41,867	5.9	13.7	43,223	5.8	12.6
• HR Administration	1,527	0.2	0.5	1,685	0.2	0.5
• Supply chain and other management services/ logistics	1,211	0.2	0.4	1,139	0.2	0.3
• Medical transcription and document management	4,172	0.6	1.4	5,365	0.7	1.6
• Content development and management and publishing	2,179	0.3	0.7	1,949	0.3	0.6
• Other BPO services	1,54,570	21.8	50.8	1,90,636	25.7	55.4

Engineering Services	**68,327**	**9.6**	**22.4**	**65,726**	**8.9**	**19**
• Embedded Solutions	7,198	1	2.4	10,550	1.4	3.1
• Product Design Engineering (mechanical electronics excluding software)	25,350	3.6	8.3	29,996	4	8.7
• Industrial automation and enterprise asset management	1,811	0.3	0.6	1,702	0.2	0.5
• Other Engineering services	33,968	4.7	11.1	23,478	3.3	6.7
Total	**3,04,499**	**42.9**	**100**	**3,44,233**	**46.4**	**100**

Source: Reserve Bank of India Survey on ICT, 2020-21

Supply chain and other management/logistics services have a 0.4% share in global service exports and are valued at US$ 0.2 billion. Supply chain is witnessing growth in areas like shipment tracking and visibility. One example of this in India is WheelsEye, an app-based online truck booking platform for SMEs with verified drivers to provide safe and specialised transport services.

The BPO segment, with an entire share of services exports at 33.3%, is dominated by other BPO services at a services exports share of 218%, followed by public relations services with a share of 4.3% of service exports, finance and accounting/auditing and book-keeping services at 5.9%. In terms of engineering services, industrial automation and enterprise management has a share of 0.6% with a value of US$ 0.2 billion.

The areas of embedded solutions and product engineering underscore the growing importance of IT services in the manufacturing context. For instance, the automotive sector can see several cross-applications of best practices from the software industry. Particularly, embedded solutions refer to devices with software algorithms loaded onto the semi-conductor processing chips. The scope for innovation within the semi-conductor industry has potential, in terms of agile manufacturing and 3-D printing methods. The move towards overcoming raw material shortages and other shortfalls in capacity have been addressed over the last five-year plan period and show promise for the prospect of leveraging digital manufacturing in the dematerialised domain of IT products and services. Integrating Indian original equipment manufacturers (OEM) with flagship companies and their nodes in specific regions has emerged as a mechanism of global production networks (Ernst and Linsu Kim, 2007). In this context, the co-evolution of software technology parks with IT service clusters is necessary (shown in Figure – 5 below).

In terms of the organization-wise distribution of software services exports, Table 5 below shows that it is skewed in favour of private limited companies. Although public limited companies are only marginally behind, the results emphasise the nature of shareholding patterns within the industry and their performance profile in terms of export orientation. Table 6 below shows the key export destinations for India's software services exports.

TABLE 6: Organization-wise distribution of Software services exports

Types of organizations	2019-20			2020-21		
	₹ Crore	US $ billion	Share (%)	₹ crore	US $ billion	Share (%)
	-1	-2	-3	-4	-5	-6
Private Limited Company	4,77,264	67.3	52.3	5,25,194	70.8	52.9
Public Limited Company	4,25,027	60	46.6	4,44,682	59.9	44.8
Others*	9,411	1.3	1.1	22,265	3	2.3
Total	9,11,702	128.6	100	9,92,141	133.7	100

**Others includes mostly LLPs/proprietor firms.*

Source: Reserve Bank of India Survey on ICT, 2020-21

TABLE 7: Software services exports – Major destinations

Region	2019-20			2020-21		
	₹ Crore	US $ billion	Share (%)	₹ crore	US $ billion	Share (%)
	-1	-2	-3	-4	-5	-6
USA & Canada	5,29,334	74.7	58.1	5,57,187	75.1	56.2
Europe	2,51,812	35.5	27.6	2,98,932	40.3	30.1
of which, UK	1,22,259	17.2	13.4	1,42,670	19.2	14.4
Asia	64,183	9.1	7	66,573	9	6.7
of which, East Asia	54,246	7.7	5.9	59,429	8	6
West Asia	7,202	1	0.8	6,747	0.9	0.6
South Asia	2,735	0.4	0.3	397	0.1	0.1
Australia & New Zealand	27,625	3.9	3	31,054	4.2	3.1
Other countries	38,748	5.4	4.3	38,395	5.1	3.9
Total	**9,11,702**	**128.6**	**100**	**9,92,141**	**133.7**	**100**

Source: Reserve Bank of India Survey on ICT, 2020-21

Table 7 above indicates the major export destinations as the United States and Canada, followed by Europe (of which UK is a dominant part), smaller Asian economies and Australia and New Zealand. There was marginal growth on a year-on-year basis from FY 2019-20 to FY 2020-21. Off-site services delivery dominated the services exports at US$ 109.9 billion in FY 2019-20 to US$ 116.4 billion in FY 2020-21. On-site services witnessed a marginal decline from US$ 19.5 billion in FY 2019-20 to US$ 17. 3 billion in FY 2020-21.

Table 8 below shows the mode-wise exports of software services. As stated above, there is a continued dominance of 'Mode 1 (cross-border supply)', followed by 'Mode 3 (by natural individuals)' and 'Mode 4 (by commercial presence)'.

Table 9 shows the activity-wise distribution of software business by foreign affiliates of Indian companies, both locally and to India.

TABLE 8: Mode-wise exports of software services[23]

Type of mode	2019-20			2020-21		
	₹ Crore	US $ billion	Share (%)	₹ crore	US $ billion	Share (%)
	-1	-2	-3	-4	-5	-6
Mode 1 (cross-border supply)	7,72,967	109	75.1	8,62,661	116.2	78.4
Mode 2 (consumption abroad)	616	0.1	0.1	1,191	0.2	0.1
Mode 3 (commercial presence)	1,17,662	16.6	11.4	1,08,031	14.6	9.8
Mode 4 (presence of natural person)	1,38,120	19.5	13.4	1,28,289	17.3	11.7
Total	10,29,365	145.2	100	11,00,172	148.3	100

[23] Ibid.

TABLE 9: Software business by foreign affiliates of Indian companies during 2020-21 – Activity distribution

(Amount in ₹ crore)			
Activity	Locally	To India	Other Countries
	-1	-2	-3
IT services	12,641	548	3,104
Software product development	448	62	149
BPO services	14,756	515	1,533
Engineering services	2,534	19	186
Other services	77,652	31,342	13,927
Total (₹ crore)	1,08,031	32,486	18,899
Total (US $ billion*)	14.6	4.4	2.5

Source: Reserve Bank of India Survey on ICT, 2020-21

4.2 Adoption of Communications Equipment in India

The Indian telecommunications sector is the second largest in the world with 1.2 billion subscribers. India's mobile economy has been driven by its widespread adoption, with wireless subscriptions representing 98% of telephone use and 788 million broadband subscribers. According to Deloitte, India is expected to reach 1 billion smartphone users by 2026, from the current 750 million. The country has also emerged as the second largest manufacturer of mobile handsets in the world[24]. India scored 49.74/100 in the Portulans Institute's Network Readiness Index, improving its ranking from 88 in 2020 to 67 in 2021 out of 130 countries surveyed. To advance India's 5G telecom infrastructure, in May 2021 the Department of Telecommunications allowed Indian telecom operators (Reliance Jio, Bharti Airtel, Vodafone Idea, and MTNL) to commence 5G trials. Non-commercial 5G trials were conducted with allocated spectrum in the mid-band (3.2 GHz-3.67 GHz), mmWave band (24.25 GHz-28.5 GHz) and the sub-1 GHz band (700 MHz), as well as in the operators' existing spectrum. India's Union Cabinet approved the Department of Telecommunications' proposal to conduct the auction in 2022, through which spectrum is assigned to the successful bidders. A total of 72097.85 MHz of spectrum with a validity period of 20 years are part of the auction, and it will encompass all available spectrum in 600 MHz (megahertz), 700 MHz, 800 MHz, 900 MHz, 1800 MHz, 2100 MHz, 2300 MHz, 2500 MHz, 3300 MHz, and 26 GHz bands. Spectrum allotted through the auction can be used for 5G or any other technology within the scope of the Access Service License. In addition to the absorption of communication technologies in the Indian context, other ecosystem elements are outlined below.

4.3 Ecosystem Elements of Indian Information and Communications Industry

India is one of the most preferred destinations, when it comes to setting-up global capability centres (GCCs). In the FY 2021, 1,400+ GCCs have more than 2,300 GCC units in India, employing more than 1.38 million professionals and it is estimated that over 45 new data centres will be established by 2025[25]. India secures 5th rank in the FTTH (Fibre to the Home) /Building Internet Subscriptions and AI Scientific Publications. Investment in Software-as-a-Service (SaaS) has increased by 62.5% over 2021 and is expected to reach US$ 6.5 billion in 2022. There are 1150+ active Indian SaaS companies; 17 of which have achieved the 'unicorn status'[26]. Internet users have increased to 80 crore in 2022 from 6 crore in 2014[27]with the country having the second highest number of internet subscribers in the world.

With their primary focus on digital technologies, the tech industry undertook over 290 M&As (mergers and acquisitions) and over 280,000 employees were reskilled in FY 2022. At 30-32% of industry revenue, digital revenues

[24] Sourced from: https://www2.deloitte.com/in/en/pages/technology-media-and-telecommunications/articles/tmt-predictions-2022.html
[25] Sourced from: https://economictimes.indiatimes.com/news/india/over-45-data-centres-spanning-approx-13-mn-sft-to-boot-up-in-india-by-2025-says-anarock-report/articleshow/93877275.cms?from=mdr
[26] A 'unicorn' is a privately held startup company valued at over US$ 1 billion.
[27] Sourced from: https://www.prnewswire.com/in/news-releases/indian-saas-to-reach-usd-100-bn-in-revenues-by-2026-says-a-new-report-by-chiratae-zinnov-870451500.html

grew five times the rate of overall services growth (Invest India).

The Government of India (GoI) has taken some major initiatives to promote the IT/ ITeS sector in India. Both central and state governments have taken steps towards developing technology solutions to digitally enable citizen services. The government plans to focus on areas such as cybersecurity, hyper-scale computing, artificial intelligence, and blockchain. Indian telecom companies are offering 1GB (gigabyte) mobile data at US$ 0.086 - one of the cheapest globally. By offering affordable data to consumers, the digital infrastructure enables ease of access to services like banking, governance and more.

Under the National Optical Fibre Network (NOPN), optical fiber in panchayats have increased from less than 100 in 2014 to 170 thousand panchayats in 2022. According to a Niti Aayog white paper, AI and new-age technology will boost India's annual growth rate by 1.3% by 2035. The Ministry of Electronics and Information Technology (MEITY) released the "National Strategy on Blockchain" to reduce fraud, speed up enforcement of contracts, and increase the transparency of transactions.

In December 2020, the GoI crafted a "National Security Directive on the Telecommunications Sector" to maintain supply chain security and avoid unsecure equipment in the country's telecom network. As per this directive, the Indian government declared a "Trusted Source/Trusted Product" list for Telecom Service Providers (TSPs). In June 2021, the GoI launched a portal for the registration and submission of required documentation by TSPs and their vendors. U.S. telecom equipment and product suppliers must contact TSPs for supply and approval from the government on this portal to sell their products and services in India. The trends in spending, outlined below, will reflect on the nature of growth in the ICT industry.

4.4 Trends in Spending in ICT Industry

In terms of the spending by the Indian ICT industry i.e., capital expenditure on procurement and investment in the FY 2020, the spending on communication services was US$ 23 billion, which increased at the rate of 11% to US$ 24 billion in 2021; This spending is currently at US$ 24.55 billion in 2022, as per advanced estimates. With respect to data centre systems, the expenditure was US$ 2.61 billion in 2020, increasing to US$ 2.76 billion in 2021 and US$ 2.86 billion in 2022. Similarly, for devices the spending in 2020 was US$ 36.01 billion, increasing to US$ 41.04 billion in 2021 and US$ 44.13 billion in 2022. Regarding IT services, the expenditure was US$ 16.35 billion in 2020, increasing marginally to US$ 18.12 billion in 2021 and US$ 19.77 billion in 2022. For Software, the expenditure was US$ 7.85 billion, increasing to US$ 9.19 billion in 2021 and US$ 10.51 billion in 2022 (United States International Trade Administration).

4.5 Current Status of Software Technology Parks and Electronics Manufacturing Infrastructure

As part of the innovation ecosystem, the key elements include the clusters (where the software technology parks in India operate) and their distribution and conditions of their operation. Further, the relative absence of an electronics manufacturing infrastructure, particularly semi-conductor manufacturing units, necessary to support these digitalisation initiatives with the deployment of new age technologies is a major constraint.

FIGURE 5: Software technology parks in India

Figure 5 above (Rao and Balasubrahmanya, 2017) shows the distribution of software technology parks in India. Almost every state has one or more software technology parks approved under a special GoI scheme that provided tax incentives and other concessions. However, given the condition of electronics manufacturing to support hardware manufacturing i.e, to embed tailor-made and specialised solutions onto automation devices, there remains much work to be done to address the hardware sector, which was largely undeveloped until now. The key constraints in this context are a poor electronics manufacturing ecosystem and quality infrastructure which the "Modified Electronics Manufacturing Clusters (EMC 2.0) Scheme" was introduced in April 2020 to create ready built sheds and plug and play facilities for attracting major global electronics manufacturers along with their supply chains. The role of supply chain management services under BPO services has been neglected in the past and will now have to be focused on while recovering from the onslaught of the COVID-19 pandemic. The scheme aims to fortify the linkages between the domestic and international market by strengthening supply chain market responsiveness, consolidating of suppliers, decreasing time to market, and lowering logistics costs. The scheme, with an initial period of three years, allows for the establishment of common facility centres and electronics manufacturing clusters through financial assistance. A further period of five years for disbursement of funds is envisioned under this scheme. Further, the IT hardware manufacturing sector has yet to develop its potential due to the lack of a level playing field vis-à-vis other competing nations. As per industry estimates, the electronics manufacturing sector suffers from a deficit of around 8.5% to 11% on account of the lack of adequate infrastructure, domestic supply chains and logistics, the high cost of finance, inadequate availability of high-quality power, limited design capabilities and focus on research and development by industry, as well as inadequacies in skill development. To position India as a global hub for electronics systems design and manufacturing, there is a need to create an enabling environment for enhancing the global competitiveness of the domestic hardware sector.

The "Production Linked Incentive Scheme" was announced in 2021 with an incentive of 4% to 2% /1 % on net incremental sales (over base year) of goods manufactured in India under the target segments of laptops, tablets, all-in-one personal computers, and servers. A comprehensive programme for the development of a semi-conductor and display manufacturing ecosystem in India, with an outlay of US$ 10 billion, was announced in 2022 with modifications. According to this, fiscal support ranging from 50% for semi-conductors, display fabs and capital expenditure for setting-up compound semi-conductors/ silicon photonics/sensor fab/and semi-conductor ATMP (Assembly, Testing, Marking and Packaging)/OSAT (Outsourced Semi-conductor Assembly and Testing) facilities has been approved. There is a target to set-up 20 such units for semi-conductor ATMP/OSAT facilities. For the semi-conductor and display fabs, the central government seeks to coordinate with state governments to create high-tech clusters with requisite infrastructure in terms of land, semi-conductor grade water, high quality power, logistics and a research ecosystem to set-up two greenfield semi-conductor and display fabs in the country. For semi-conductor design companies, a design linked deployment incentive of 6%-4% on net sales for a period of five years has been allowed, in addition to financial assistance. This support is being extended to 100 semi-conductor design companies for integrated circuits, chipsets, System on Chips (SoC), systems and IP cores and semic-onductor linked design. The target is to build 20 such companies with a turnover of INR 1500 crore in the next five years[28]. In terms of the development of supply chains for electronics manufacturing for higher value addition, a "Scheme for the Promotion of Manufacturing of Electronic Components and Semi-Conductors" was started in April 2020 to make India a significant design and manufacturing hub for electronics in the global value chain. Media reports suggest that major private players like the Tata Group and Vedanta Group are planning to make investments in semi-conductor manufacturing in India over the next few years.[29]

The scope of engineering services, particularly product services engineering, requires the creation of an ecosystem to promote state-of-the-art technology in AI, 3-D printing, and agile manufacturing to enable the promise of digital manufacturing in the ICT industry. There is the need for greater integration of academic institutions, research institutes, firms and startups working in niche and new-age ICT service segments with a tailor-made focus of solutions in specific domains (healthcare, etc.) to open up the potential for knowledge spillovers. The orientation of activity around these software technology parks can be and is currently being enabled using the cluster principle. Advances in digital manufacturing can only buttress the increasing first- generation digital automation of engineering and service-based industries and therefore, initial investments in digital infrastructure at generating data from each step of the manufacturing process is the first step towards successful full-scale deployment of digital manufacturing. The logistics and costs involved in such automation have however witnessed adoption challenges on the ground by a manufacturing sector that is fragmented in terms of composition and the ability to invest in basic, let alone critical, digital manufacturing infrastructure.

India's IT clusters based on the size of exports are mostly in South India, mainly Bangalore, Hyderabad, and Tamil Nadu. However, the rise of Tier 2 cities (like Chennai, Kolkatta, Pune, Vishakhapatnam, etc.) has further intensified the trends in business process outsourcing services and widened the reach of the revolution currently underway for the past three decades. Integrating the electronics manufacturing infrastructure and ecosystem, creating an innovation ecosystem for digital manufacturing technologies as well as a research and innovation ecosystem with Centres of Excellence (CoE) therefore remain key to enabling India's digital manufacturing revolution. The current technological trajectory is likely to reveal greater insight into the potential for integrating digital manufacturing services into product manufacturing to promote embedded software, as well as enhance the scope for hardware manufacturing in the Indian context.

4.6 Technological Trajectory of India's Software Exports

The technological trajectory of India' software industry is primarily geared towards the services component. A lot of studies attribute the growth of India' software industry to a case of benign neglect by regulators (Arora and Gambardella, 1990). The guided nature of typical technological trajectories is therefore not evident in the Indian case, where growth of this industry has been more organic. However, concerted regulatory efforts, discussed above, aim to provide greater incentives to activities like semi-conductor manufacturing, which are critical to any growth in the provision of embedded solutions, particularly engineering services in product design. The development of BPO services, especially engineering and product service engineering, however nascent, underscores the need for Industry 4.0 technologies to enhance the digital maturity of organizations using state-of -the-art digital automation. While the developed countries have also been unable to deploy digital manufacturing in large measures, due to competitive and pricing pressures that become evident in

[28] Sourced from: https://economictimes.indiatimes.com/small-biz/sme-sector/with-rs-76000-crore-pli-scheme-india-set-to-action-its-semiconductor-fab-vision/articleshow/88848107.cms

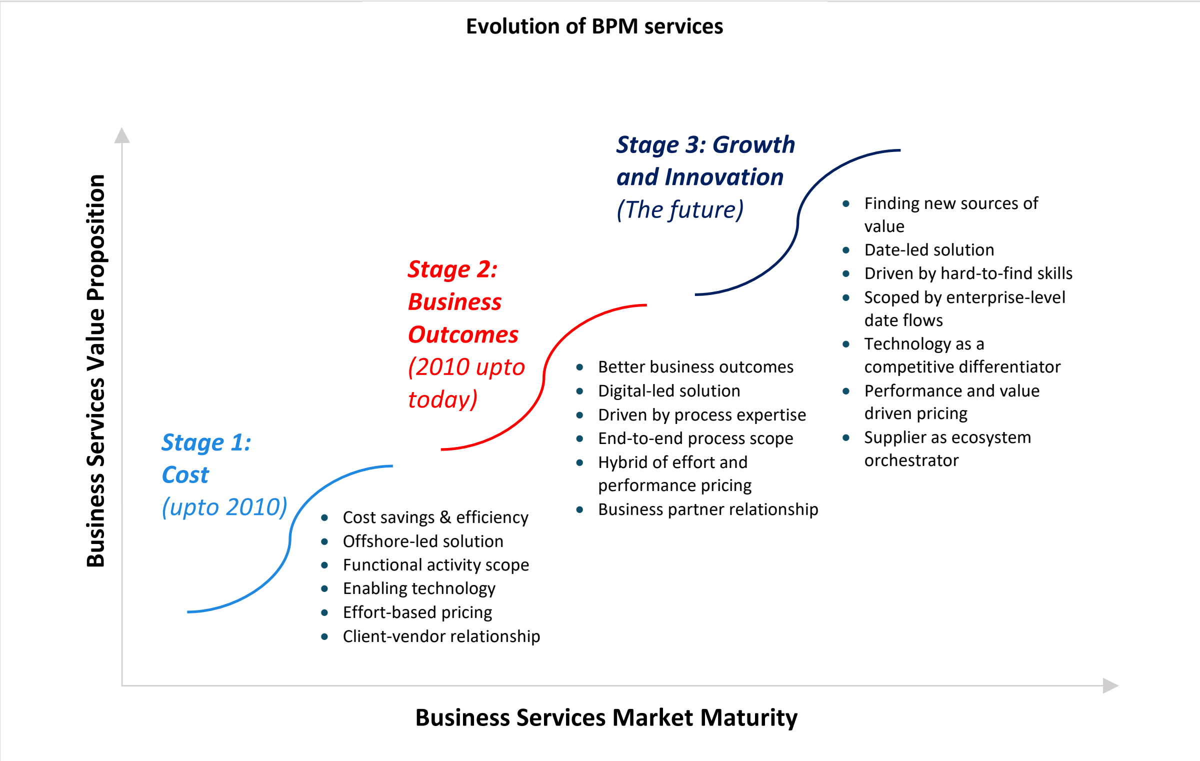
[29] Sourced from: https://news.abplive.com/technology/tata-sons-semiconductor-manufacturing-india-chairman-natarajan-chandrasekaran-global-chip-supply-chain-1568657

the current stage of the service segments that digital manufacturing services operate within, developing country firms struggle with basic automation to leverage these solutions. For this, understanding the BPO services evolution is a necessary context for how engineering or manufacturing transformation can take shape.

4.7 Evolution of India's BPO/BPM Services in Terms of Engineering or Manufacturing Transformation in Indian ICT Industry

For the management of engineering or manufacturing transformation, we first have to ncentivi the features typical to each stage of the evolution that become apparent in relation to the BPO services industry. Figure 6 below shows the current stage of evolution the BPO services industry is at in terms of the engineering or manufacturing transformation. According to NASSCOM (Avasant Engineering and Manufacturing Transformation Cloudification Approaches Critical Mass, 2022), we are currently in Stage 2, where better business outcomes are contingent upon digitally led solutions, driven by process expertise, a feature characteristic of this industry. The future of growth and innovation involves finding new sources of value from data-led solutions, particularly in areas of emerging skill sets as traditional jobs automate. A lot of support institutions and infrastructure like cloud computing digital manufacturing routines become important in this context.

FIGURE 6: The evolution of BPM sources



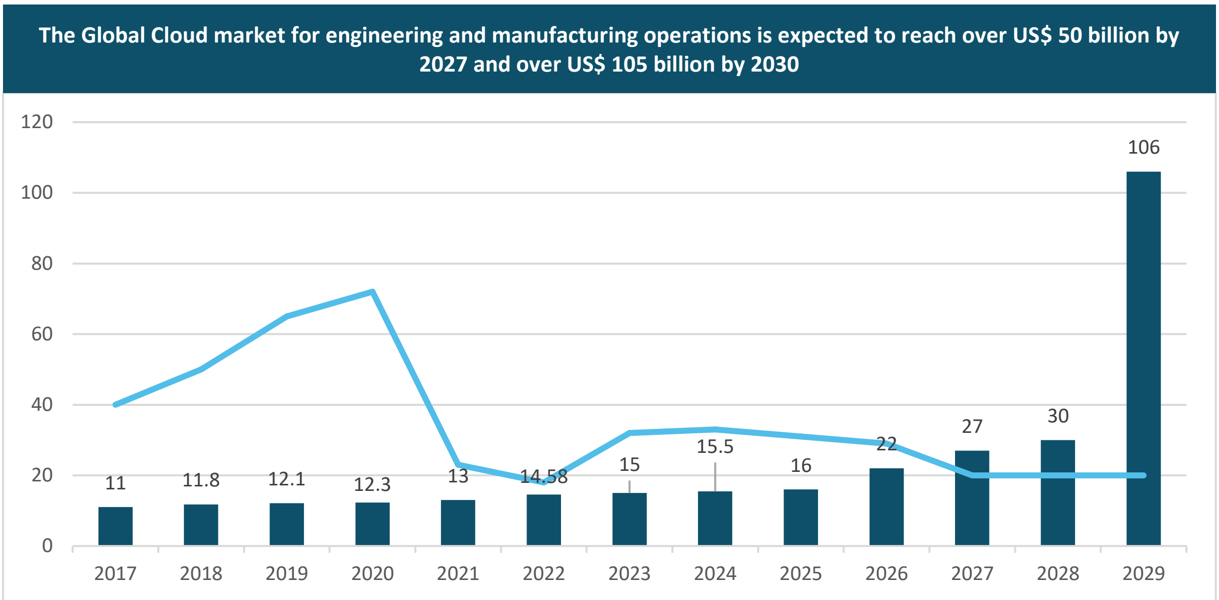
Source: HFS Research in partnership with NASSCOM, 2022

4.8 Status of Digital Manufacturing Infrastructure and Artificial Intelligence Ecosystem

Though the traditional service profiles comprise the backbone of India's exports to major export destinations under various modes of supply, there is the need for creating new emerging niches to support digital manufacturing infrastructure. In this context, the global cloud serves as the powerhouse that contains the information obtained from the data-rich and at the same time intensive manufacturing processes and other operations of the target industry, where it is sought to be implemented. The global cloud market is expected to reach US$ 100 billion in 2030 (NASSCOM -Avasant Engineering and Manufacturing Transformation, 2022) and will continue to have a double digit CAGR over the next five to seven years. Applications with higher computing and collaboration requirements, such as design systems, are expected to move to the cloud faster in the short- to medium-term, while manufacturing and operations systems will pick up pace in the long-term. Industries like automotives, manufacturing, healthcare, and life sciences, with high product innovation requirements are ahead in adopting the cloud for engineering and manufacturing operations with the share of services in the cloud market being 27-32%. The role of service providers has become critical as a key enabler in the adoption of cloud services for this purpose on account of the pressing need for business innovation, faster product roll-out, and cost containment.

Due to the status of manufacturing as a business process, India accounts for 40% of the global sourcing spend in respect of such services (NASSCOM, The Evolution of BPM services: Cost, Outcomes and Growth, 2022). The future of BPM is performance and value-driven with a key emphasis on skills, particularly problem-solving and soft skills. Finding new sources of value remains key in this context, while the creation of infrastructure such as cloud computing remains important for digital manufacturing transformation.

FIGURE 7: Estimated global cloud market



Source: NASSCOM – Avasant Report, 2022

NASSCOM in its recent report "Artificial Intelligence Game Changers: Accelerating India with Innovation" (2021)[30] outlines the prospect of value addition to the extent of US$ 50-55 billion in the case of telecommunications and information technology (NASSCOM Unlocking Value from Data and AI-The India Opportunity, 2020). India has 5 million workers in AI and is positioned 6th in Stanford's Global AI vibrancy ranking and aces the inclusivity parameter. India is ranked 8th in terms of patent filings on AI and 45% of companies have increased their adoption of AI which is favourable by global standards (PwC report, 2020). Of these, 50% of companies are startups which is an encouraging sign for the future of digital manufacturing technologies, services, and product offerings. From a total of 300+ AI case studies outlined in this report, startups and enterprises were major contributors at 44% and 43% respectively, with the remainder 9% from academia, and 4% from government and non-governmental organizations[31]. Technology, media and telecommunications comprise 27% of the case studies by industry verticals, followed by manufacturing and industrial automation at 18%. AI powered operational intelligence is in use to predict failure probabilities of machines accurately and recommending risk mitigation plans. Eugenie AI is an AI powered operational failure intelligence solution, which analyses streams of data from multiple sensors from multiple machines at huge volumes and speed. It uses this data to predict accurate failure probabilities for each machine and recommend mitigation plans. Diagnostics are processed on a real-time basis free from human intervention and conduct a root cause analysis. It is one of the leading examples of cost saving and greater operational efficiency. With these advantages, it has also led to decreased greenhouse gas emissions. Cases of the deployment of such manufacturing technologies abound, but the challenges associated with adoption remain.

[30] "Artificial Intelligence Game Changers: Accelerating India with Innovation" (2021): https://digitalindia.gov.in/writereaddata/files/NASSCOM%20AI%20gamechangers%20compendium%20-%202021%20edition.pdf
[31] Sourced from: https://www.pwc.in/consulting/technology/data-and-analytics/ai-an-opportunity-amidst-a-crisis.html

5.
Policy Landscape

Policy Landscape

Information and Communication Technologies (ICTs) have been a key driver of economic development and social transformation in both industrialised and developing countries for over two decades. The World Bank's "World Development Report 1998-99" identified knowledge, not capital, as the key to the social and economic transformation of a country. That same year, the United Nations Commission on Science and Technology for Development (UNCSTD) published an influential report, by Professor Mansell and Dr Uta I of the London School of Economics, entitled "Knowledge Societies: Information Technology for Sustainable Development". India was one of the countries that financed the Working Group and the editorial board meetings. The report examined the available evidence on the ICT-growth link in developing countries and the potential for building innovative 'Knowledge Societies' that can support their development goals (UNCSTD, 2013). Furthermore, the United Nations Conference on Trade and Development (UNCTAD) created an "ICT Policy Review Programme" in 2009 to provide technical assistance and policy advice to countries requesting assistance in building and maintaining a dynamic and responsive ICT policy environment. Such effoncentivizised the need to actively foster ICT-led development and strengthen the ICT innovation in the national development agendas of developing countries.

ICT has been driven by innovation and in turn, it leads to innovative practices and even businesses. Firms do not innovate in isolation; innovation is an interactive process among a wide variety of actors (Edquist, 1997, 2001). In the innovative process, firms interact with other firms as well as with non-firm actors/institutions (such as universities, research centres, government agencies, financial institutions, etc.) and their actions are shaped by these interactions in the innovation ecosystem (Lundvall, 1993; Carlsson, 1995; Edquist, 1997). Policy leaders need to work together with stakeholders in the ICT innovation ecosystem to understand the ecosystem challenges, needs and opportunities. With the rapid growth of ICT components and networks, the opportunities and challenges presented by ICT are also subject to rapid change (UNCSTD, 2013). Therefore, policymakers also need to better understand the impediments to the diffusion and use of information technologies in this ever-changing landscape of technologies and services.

Explained below are the core policies of the ICT sector in India that are addressed along with the supporting policies that have a bearing on the ICT sector.

5.1 Core Policies of the ICT Sector

Globally, India has bncentivizised as a knowledge economy due to its impressive ICT industry. The emergence of a strong ICT industry happened due to concerted efforts on the part of the government, particularly since the 1980's, and a host of other factors like the government-diaspora relationship, private initiatives, the emergence of software technology parks, patterns of spatial agglomeration in the IT sector and public-private partnership (Mathur, 2006). Information Technology and Business Process Management is one of the focus sectors under the Government of India's "Make in India" initiative. The government continues to play a crucial role in facilitating technology access, both at the national and state level (Das and Sagara, 2017).

National Policy on Information Technology 2012 (NPIT 2012)

Developmental challenges in education, healthcare, skill development, financial inclusion, governance, etc., can effectively be overcome with the deployment of ICT in all sectors of the Indian economy. The "National Policy on Information Technology" (NPIT 2012) was approved in September 2012, rooted in the conviction that both ICT and electronics have the power to transform the Indian economy, society and governance. The policy aims "to strengthen and enhance India's position as the global IT hub and to use IT and cyberspace as an engine for rapid, inclusive and substantial growth in the national economy."

It is important to highlight that in accordance with the Global Innovation Index (GII), while India has been ranked 46th out of 132 economies, the country's ICT access ranking declined from 108 in 2012 to 111 in 2021. With regards to 'ICT access', the strategies of NPIT 2012 highlight the need "to enable long-term partnerships with Industry for: i. Use of ICT in cutting-edge technology; ii. Driving development of new ICT technologies through strategic sectors; iii. Facilitating growth of IT SMEs and the use of IT across all SMEs" (MEITY, 2012:7). The policy also outlines the need to intervene and "promote use of IT in key economic sectors such as Construction, Textiles, Pharmaceuticals, Banking, Finance, Retail, Energy, Automobiles, Healthcare, Education, Agriculture, Engineering Services, Transport and Logistics for improved efficiency and productivity" (MEITY, 2012:7).

National Telecom Policy 2012 (NTP 2012)

In the same year, the "National Telecom Policy 2012" (NTP 2012) was also introduced, laying special emphasis on providing affordable and effective quality telecommunication services for all citizens across the country, including those in rural and remote areas. Using telecommunications as a platform, NTP 2012 endeavors to transform India into a knowledge-based economy. It also aims to create an investor-friendly environment for attracting additional investments in the telecom sector and generating manifold employment opportunities in various segments of it (MEITY, 2012).

The Information Technology Act 2000 (IT Act 2000)

It is clear that ICT has a significant positive impact on people, businesses, employment, education and on the provision of basic citizen services, but it also raises concerns about data security and cybercrime. The Information Technology Act 2000 (IT Act 2000) is the prime legislation in India dealing with cyber offences and electronic commerce. It is based on the United Nations Model Law on Electronic Commerce adopted by the United Nations Commission on International Trade Law (UNCITRAL). The IT Act 2000 is applicable to the whole of India and also applies to "an offence or contravention committed outside India by any person if the act or conduct constituting the offence or contravention involves a computer, computer system or computer network located in India" (MEITY, 2000).

The 1860 Indian Penal Code, the main criminal code of India, intended to cover all substantive aspects of criminal law, was found to be inadequate in dealing with the hi-tech nature of cyber offences and required ncentivizeontion which is dealt with under the IT Act 2000. Similarly, it also aims to amend certain provisions of the Indian Evidence Act, 1872, the Ba'ker's Book Evidence Act 1891, and the Reserve Bank of India Act, 1934 (Kolekar, 2015). The key objectives of the IT Act 2000 are: a) To provide legal recognition of e-records; b) To provide legal recognition of digital signatures; c) To provide legal recognition to electronic governance; d) To provide punishment for cyber offences; e) To establish the Cyber Appellate Tribunal – a separate mechanism to resolve matters as an appealable agency arising from authorities appointed under the Act (Kolekar, 2015).

The provisions of the IT Act 2000 seek to protect only 'sensitive data'. The Data Privacy Rules refer consistently to 'sensitive personal data or information' as the subject of protection, but experts argue that sensitive data is only one compartment of 'personal information'. The phrase 'sensitive personal data or information' gives the impression that these rules apply only to sensitive data and not to non-sensitive 'personal information' (Joseph et al., 2020). Further, the Data Privacy Rules do not specify any timeframes for the retention of sensitive data. Government has yet to frame rules implementing the retention provision (Menon, 2013).

The Information Technology (Amendment) Act 2008

The rapid emergence of IT Enabled Services (ITeS) like e-governance and e-transactions raised concerns about data protection and privacy and created a need for more stringent provisions. In addition to that, the increase in cyber-crimes, cyber terrorism and online scams had necessitated the implementation of the strict penal provision, hence in 2008, the central government brought key amendments to the Information Technology Act 2000 (Kolekar, 2015).

But data theft and misuse issues continue to linger, shaking investor confidence and raising concerns about the safety of data and quality of ITeS in India. In November 2012, Andhra Pradesh State IT Minister, Ponnala Lakshmaiah, wrote a letter seeking the formulation of a new data protection act for IT companies. Stressing the need for specific and stringent legislation in line with the EU or the US, he argued that "the IT Act must provide for data protection and privacy in order to sustain investor confidence, especially among foreign entities that send large amounts of data to India for back-office operations".[32] The government also needs to bring out a robust data protection regime to protect the personal data of individuals. The Personal Data Protection Bill (PDPB) was introduced by MEITY in Lok Sabha on December 11th, 2019, on the basis of recommendations made by the Committee of Experts on Data Protection constituted by the Government of India. Since then, it has undergone several iterations and has now been referred to the Joint Parliamentary Committee comprising members of parliament (both houses) for detailed study. Media reports suggest that the government may soon replace the two-decade old IT Act with the new Digital India Act and introduce new regulations to replace the PDPB[33]. These upcoming changes to the data protection regime must reflect the world's changing approach to data protection apace with international counterparts.

[32] Sourced from: http://archive.asianage.com/hyderabad/new-data-protection-act-sought-467

[33] Sourced from: https://economictimes.indiatimes.com/small-biz/policy-trends/one-of-the-last-few-countries-without-modern-data-protection-law-why-india-needs-an-urgent-revamp/articleshow/91556170.cms?from=mdr

National Manufacturing Competitiveness Programme 2007 (NMCP)

In 2007-08, the Ministry of Micro, Small and Medium Enterprises (MSME) launched a five-year “National Manufacturing Competitiveness Programme” (NMCP) with the aim to develop global competitiveness among Indian MSMEs in the face of stiff competition from China and other neighbouring countries. Ten schemes were drawn up under the programme (and implemented in the Public-Private-Partnership (PPP) mode) that targeted enhancing the entire value chain of the MSME sector, starting from lean manufacturing and technology and quality upgradation support, the setting-up of design clinics and ‘Mini Tool Rooms’, to market development assistance and entrepreneurial support through incubators. ZED certification (Zero Defect and Zero Effect Financial support) was also provided under this.[34] Despite the good intent, the government faced challenges in implementation as it was basically a supply-side initiative and MSMEs were hesitant to disclose their data and invest their contribution.

Digital India Programme

ICT is a powerful tool for empowerment and income generation, and it is used by knowledge economies to create, disseminate, and apply knowledge for growth. By leveraging its strength in ICT, India can also become a leading knowledge-based economy. Recognising this, the Government of India launched the “Digital India” programme in 2015 with a vision “to transform India into a digitally empowered society and knowledge economy” (MEITY, 2015). It is an umbrella programme implemented by the entire government, with overall coordination being done by the Department of Electronics and Information Technology (DEITY). This calls for wider consultations across government, industry, civil society, and citizens to discuss various issues and arrive at innovative solutions for achieving the desired outcomes of Digital India. The DEITY has launched a citizen engagement platform named “myGov” (http://mygov.in/) to facilitate collaborative and participative governance by seeking public opinion on issues of public interest and welfare.

Digital India aims to provide the much needed thrust to the nine pillars of growth, where each of these areas is a complex programme in itself and cuts across multiple ministries and departments (MEITY, 2015). Table 10[35] lists the nine pillars of Digital India, including each pillar’s significance, challenges in implementation and potential solutions:

TABLE 10: Nine Pillars of Digital India.

Pillar	Significance	Challenges	Solution
Broadband highways	• Broadband networks to span India’s cities, towns, and villages. National Information Infrastructure (NII) to integrate the network and cloud infrastructure in the country to provide high-speed connectivity and cloud platform to various government departments up to the panchayat level	• Lack of communication and content to drive network usage. • Project delays or time overrun. • Lack of robust infrastructure	• Content and service partnerships with telecom companies and other firms aimed at providing affordable internet access
Universal access to phones	• Focuses on network penetration • Ensures mobile coverage to remote uncovered villages	• Spectrum crunch that can drive up cost and reduce quality	• Intensive and complex traffic management by mobile service providers • Spectrum sharing
Public internet access	• Strengthening of Common Service Centres as viable and multi-functional endpoints for delivery of government and business services	• Slow adoption and uneven implementation • Gaps in delivery of e-Governance services	• Maximize delivery of e-services to citizens • Strengthening of CSC network by ensuring standardization and capacity building
e-Governance – Reforming Government through Technology	• Using IT to simplify and make the government processes more efficient and delivery of government services more effective	• High implementation cost • Data protection and privacy concerns • Language barrier	• Ensure strong network security at all levels of operation. Minimizing cybersecurity risks • Building awareness about the e-Governance activities in Indian vernacular languages

[34] Sourced from: https://www.startupindia.gov.in/content/sih/en/government-schemes/national_manufacturing_competitiveness_programme.html
[35] Sourced from: https://digitalindia.gov.in/content/programme-pillars

eKranti - Electronic delivery of services	• Comprises 44 Mission Mode Projects spanning e-education, e-Healthcare and technology for farming, security, financial inclusion, justice, planning and cyber-security	• High implementation cost and time	• Leveraging emerging technologies like Mobile and Cloud • Maintaining citizen centricity, service orientation and transparency
Information for All	• Online hosting of government documents and information for citizens.	• Mostly one-way information flow, avoiding criticism	• Democratizing the information flow • Minimizing cybersecurity risks
Electronics Manufacturing	• Promoting electronics manufacturing in the country with target of NET ZERO Imports	• Duty anomalies mar domestic electronics manufacturing • Heavy dependence on imports	• Correction of duty structure • Geographic inclusions of all states and union territories for innovation in electronics • Subsidizing training and internships • Incentivizing research and IP development.
IT for jobs	• Providing training to the youth in the skills required for availing employment opportunities in the IT/ITES sector	• Poor quality of manpower • Under-trained and mismatched to industry needs	• Strong industry-academia linkages to figure out industry needs and teach/train accordingly
Early harvest programmes	• Consists of projects which are to be implemented within a short timeframe.	• Inadequate usage • Implementation and budgeting issues	• Public Private Partnership models to be explored for sustainable development of digital infrastructure

The key initiatives undertaken under the Digital India programme to promote information technology and the information technology enabled services (ITES) industry in the country[36] are:

- "India BPO Promotion Scheme" (IBPS) seeks to incentivise the establishment of 48,300 seats in respect of BPO/ITES operations across the country. This would help in capacity building in smaller cities in terms of infra & manpower and would become the basis for the next wave of IT/ITES-led growth.
- The "North East BPO Promotion Scheme" (NEBPS) seeks to incentivise BPO/ITES operations in the North East Region (NER) for the creation of employment opportunities for the youths and growth of the IT-ITES industry.
- "Bharat Interface for Money" is an app that makes payment transactions simple, easy and quick using Unified Payments Interface (UPI). It enables direct bank-to-bank payments instantly and collects money using a mobile number or payment address.
- "eBiz" seeks to improve the business environment in the country by enabling fast and efficient access to Government-to-Business (G2B) services through an online portal. This is being implemented by Infosys Technologies Limited under the aegis of the Ministry of Commerce & Industry, Government of India. This will help in reducing unnecessary delays in various regulatory processes required to start and run businesses.
- The "GST System Project" is an IT initiative that seeks to establish a uniform interface for the taxpayer and a common and shared IT infrastructure between the centre and states. The portal envisions becoming a trusted National Information Utility (NIU) which provides a reliable, efficient and robust IT backbone for the smooth functioning of the Goods & Services Tax regime.
- The Centre of Excellence for Internet of Things (IoT) was announced to jump start the IOT ecosystem taking advantage of I'dia's IT strengths and to help the country attain a leadership role in the convergent area of hardware and software. The main objective of the centre is to create innovative applications and domain capabilities and help build industry capable talent, a startup community and an entrepreneurial ecosystem for IOT.
- Cyber Swachhta Kendra (Botnet Cleaning and Malware Analysis Centre) seeks to create a secure cyberspace by detecting botnet infections in India and notifying, enabling cleaning and securing systems of end users so as to prevent further infections. It is set-up in accordance with the objectives of the National Cyber Security Policy, which envisages creating a secure cyber ecosystem in the country. This centre operates in close coordination and collaboration with internet service providers and product/antivirus companies.

[36] Sourced from: https://www.digitalindia.gov.in/di-initiatives

Digital India is an ambitious initiative by the Government of India and is by far, the biggest ever conceived. The MEITY's outlay for Digital India in the Budget 2022-23 has jumped 67.13% from last year (Ministry of Finance, 2022). Though India's road to digital transformation was paved by important government initiatives that led to the development of new digital platforms for the citizens and improved access to such platforms, the policy also faces certain drawbacks such as the lack of education, lack of infrastructure and required technology, financial and technical issues, attitudes of citizens as well as government personnel, cyber-crimes and a lack of confidence (Shallu and Meena, 2019). The goals of Digital India are laudatory and can boost India's economy, but they are still far away as most of the nine pillars are facing serious challenges in implementation (Boro M.C., 2017). Such challenges slow down effective digitisation and increase cyber-crimes, which is a major reason for the lack of confidence. High initial costs for transition from legacy systems also require economic resources, proper training and continued human will for success of digitisation, etc. (Beriya, 2021).

National Intellectual Property Rights Policy 2016 (IPR Policy 2016)

Government support is needed for businesses not only to innovate new technologies, but also to safeguard their technological inventions with effective IP protection. In May 2016, the Department for Promotion of Industry and Internal Trade (DPIIT) rolled out the country's first "**National Intellectual Property Rights (IPR) Policy 2016**" to foster creativity and to implement a strong IP-led innovation model. This policy encourages IPR generation for ICT technologies, including those relating to Indian cybersecurity. It supports small technology firms in safeguarding their IP rights in ICT focus areas through easy-to-use portals. Prof. Sunil Mani, in his critique on the "New IPR Policy 2016: Not based on evidence" argues that even before the IPR policy, India had a functioning legal regime with individual acts on patents, trademarks, designs and geographical indications, all of which were suitably amended over time to comply with TRIPS (Agreement on Trade-Related Intellectual Property Rights) (Mani, 2014). He contends that "some measures in the IPR policy are laudable but the policy objectives are not evidence-based and are tailor-made to suit the requirements of the western governments." He further argues that the government should rather be spending time and money on improving the performance of patent offices that are understaffed and underfunded leading to major delays in patent approval in the country.

Recently, MEITY has launched a **"Support for International Patent Protection in Electronics & Information Technology"** (SIP-EIT) scheme, to provide financial support in international patent filing to MSMEs and technology startups in the ICT sector. It offers inventors reimbursement of up to INR 15 lakh for each international patent filing. In addition, the scheme provides financial support to education institutes, MEITY, societies, etc., for organising seminars and workshops on IPR awareness among various stakeholders.

It is evident that India has been taking a decisive stand on patents to the advantage of domestic manufacturers, but it needs more such incentive programmes, with effective and widespread implementation. India has built pockets of knowledge-based growth but has not yet translated this into a broader economic model. Actions to promote knowledge-based economies will require strong, coordinated government policies coupled with investment in ICT (ADB, 2014).

National Digital Communications Policy 2018

The "**National Digital Communications Policy 2018**" seeks to unlock the transformative power of digital communications networks – to achieve the goal of digital empowerment and improved well-being of the people of India. Towards this end, it attempts to outline a set of goals, initiatives, strategies and intended policy outcomes. The National Digital Communications Policy adopts a three-pronged approach of 'Connect-Propel-Secure' encompassing all aspects of digital communications. Under this approach, it aims to accomplish the following strategic objectives by 2022:

- Connect India: Creating a robust digital communication infrastructure.
- Propel India: Enabling next generation technologies including: 5G, artificial intelligence (AI), machine learning (ML), Internet of Things (IoT), augmented reality (AR), virtual reality (VR), robotics, cloud and big data and services through investments, innovation, indigenous manufacturing and IPR generation.
- Secure India: Ensuring digital sovereignty, safety and security of digital communications.

The policy document states that "it is hoped that this policy will facilitate the unleashing of the creative energies of citizens, enterprises and institutions in India; and play a seminal role in fulfilling the aspirations of all Indians for a better quality of life". This can only be accomplished if the policy visions and objectives are supported by a credible implementation plan which tracks numbers, assesses any gaps and ensures smooth execution with no time and cost overruns[37].

National Policy on Software Products (NPSP) 2019 and Next Generation Incubation Scheme (NGIS) 2020

The Government of India set its focus on the indigenous software industry with the announcement of the National Policy on Software Products (NPSP) on 28th February 2019. The policy aims to position India as a global power in the software industry, driven by innovation, rapid commercialisation and sustainable IP. It offers to bring together the industry, academia and the government to create a robust Indian software products ecosystem. Further, it aims to align with other government initiatives such as Startup India, Make in India, Digital India, Skill India etc., to promote technology start-ups and specialised skill sets (MEITY, 2019). A year later, Next Generation Incubation Scheme (NGIS) was launched with a vision to promote and support innovative startups working in software product development, including embedded electronics. With a budgetary outlay of INR 95.03 crore over 3 years, NGIS aims to incentivise 300 start-ups from 12 Tier II cities by offering a series of financial incentives, physical incentives and soft support. NGIS is being executed by Software Technology Parks of India (STPI), a premier science and technology organization under MEITY that promotes startups working in emerging technologies. STPI has been running a series of online challenge hunts (called CHUNAUTI) under NGIS for Advanced Uninhibited Technology Intervention. So far, 171 startups have been selected across multiple domains and 38 have been onboarded, which have shown exceptional innovation in their respective sectors.[38]

National Policy of Electronics 2019 (NPE 2019)

By 2025, India aims to achieve a GDP of US$ 5 trillion and a digital economy of US$ 1 trillion. As electronics underpin manufacturing, the electronics manufacturing sector is given high priority as one of the key pillars of the GoI's "Make in India", "Digital India" and "Start-up India" programmes. According to the vision document released by the Ministry of Electronics and IT (MEITY) in association with the India Cellular & Electronics Association (ICEA), electronics manufacturing in India is expected to quadruple to US$ 300 billion by 2026. With the increased pace of digitalisation during the pandemic, demand for electronics products remained strong and is expected to continue to rise. Moreover, emerging technologies are driving up demand for new electronics products, which are becoming ubiquitous, embedded in all products including automobiles. Recognising India's potential to emerge as a leading force in the electronics space, in February 2019 the Union Cabinet approved the "National Policy of Electronics 2019 (NPE 2019)", which replaces the "National Policy of Electronics 2012". The policy envisions positioning India as a global hub for Electronics System Design and Manufacturing (ESDM) by encouraging and driving capabilities in the country for developing core components including chipsets and creating an enabling environment for the industry to compete globally.

The NPE 2019 was prepared after extensive stakeholder consultations, including industry, industry bodies, key ministries/ departments of GoI and state governments. It is considered to be a major policy initiative of the GoI, which has a direct bearing on the ESDM sector. It is only with government support that the electronics manufacturing industry ncentilise resources efficiently and build sustainable domestic capabilities to address environmental and social challenges. Inspired by the Prime Minister's vision to increase exports and India's share in the global supply cha–ns - "Local goes Glob–l" - MEITY also released a Vision Document titled "Increasing India's Electronics Exports and Share in Global Value Chains" on 2nd November 2021**.** The vision focuses on the opportunities and key inputs to enhance India's share in the global value chain and build large-scale manufacturing capabilities to achieve a substantial share in global electronics exports.

Production Linked Incentive (PLI) Schemes

In order to push the vision of NPE 2019 further and incentivise the domestic electronics manufacturing industry as part of the Atmanirbhar Bharat Abhiyaan, the GoI introduced three schemes: **"Production Linked Incentive Schemes (PLI) for Large Scale Electronic Manufacturing and IT Hardware", the "Scheme for Promotion of Manufacturing of Electronic Components and Semi-Conductors" (SPECS) and the "Modified Electronics Manufacturing Clusters Scheme" (EMC 2.0).** SPECS and EMC 2.0 were notified in April 2020 while the PLI for IT hardware was notified in March 2021. These schemes have been constructed to create economies of scale, promote a domestic electronics supply chain of components and develop infrastructure and common facilities for the sector (Invest India). They can also provide an opportunity for multinational companies to bring their

[37] Sourced from: https://telecom.economictimes.indiatimes.com/tele-talk/hits-and-misses-of-national-digital-communications-policy-2018/3101
[38] Sourced from: https://ngis.stpi.in/chunautihome/

global manufacturing and supply chain capabilities to India[39].

Design Linked Incentive (DLI) Scheme

In December 2021, the Ministry of Electronics and Information Technology announced the "Design Linked Incentive (DLI) Scheme" to "offset the disabilities in the domestic industry involved in semi-conductor design in order to not only move up in the value-chain but also strengthen the semi-conductor chip design ecosystem in the country". The scheme has three components – Chip design infrastructure support, product design linked incentives and deployment linked incentives. The C-DAC (Centre for Development of Advanced Computing), a scientific society operating under the MEITY, will serve as the nodal agency for the implementation of the scheme (MEITY, 2022). The scheme offers financial incentives and design infrastructure support to domestic firms, startups and MSMEs engaged in semi-conductor design for integrated circuits (ICs), chipsets, system on chips (SoCs), systems & IP cores and semi-conductor linked design(s) over a period of 5 years starting 1st January 2022 (MEITY, 2022).

In December 2021, the MEITY also launched a **"National Strategy on Blockchain"** in an endeavor to create a vigilant and trusted collaborative digital ecosystem in the country that can provide a transparent and open framework for offering e-governance services to businesses. It also aims to make India a global leader in terms of research and development and harness the benefits of emerging blockchain technology. Such initiatives will go a long way in creating a nationwide ecosystem for creating trusted digital platforms and the development of relevant applications using these platforms in various domains.

The COVID 19 pandemic has provided a compelling opportunity for different stakeholders in the innovation ecosystem to interact and work in unison and ICTs can facilitate these interactions and enable innovation at all levels. Amid the pandemic, the Ministry of Science & Technology released the **"Draft 5th National Science, Technology, and Innovation Policy"** (Draft STIP 1.4 Dec 2020) for public consultation. The policy aims to promote traditional knowledge systems, develop indigenous technologies and encourage grassroots innovations by leveraging ICT. The policy document advocates the use of ICT in addressing issues of accessibility and promoting research and innovation. It also aims to leverage ICT for active learning practices and for fostering science and technology-enabled entrepreneurship in India. The policy recognises the interplay between technology and sustainability and its impact on society, environment and economy. Realising the need for the development and deployment of sustainable technologies, it states that "development of sustainable technologies should be of paramount importance for India's ICT sector." Thus, the draft STIP envisages a greater role for ICT in creating a vibrant R&D ecosystem that promotes research and innovation for both individuals and organizations.

5.2 Initiatives for the Future Workforce

The Indian economy is deeply shaped by technological developments using ICT. The COVID-19 pandemic has further accelerated the growth of the digital economy and ICT skills have become critical to this growth. Advanced IT systems necessitate a skilled workforce of a higher degree and quality. Firms employing a more skilled workforce are likely to adopt more advanced IT tools (Lal, 1999). Several studies (Rada, 1982; Sargent and Matthews, 1997) show that as firms adopt more and more integrated manufacturing models, the interaction between different systems makes the skill content of the workforce more important. Studies (Romijn, 1997; Doms et al., 1997) that have analysed the relationship between the adoption of new technologies and the skill composition of the workforce have found the qualifications of employees having a positive effect on the adoption and acquisition of new technologies. Entrepreneurial abilities play an important role in the acquisition and adoption of new technologies (Dosi, 1988a; Utterback and Suarez, 1993; Cohen, 1995; Lal, 1998; Lal, 1999).

National Mission on Education through Information and Communication Technology (NMEICT)

The Ministry of Human Resource Development (MHRD), Government of India launched the "National Mission on Education through Information and Communication Technology" (NMEICT) in 2009 as a centrally sponsored scheme to leverage the potential of ICT, in teaching and learning processes for the benefit of all the learners in higher education institutions. The objective is for the Indian economy to sustain a high growth rate through capacity building and knowledge empowerment of the people and to promote new, upcoming multi-disciplinary fields of knowledge. Some of the key projects sponsored by the MHRD under the NMEICT include: virtual labs - providing remote access to simulation-based labs in various disciplines of science and engineering; e-Yantra - providing education in embedded systems and robotics; A-VIEW - a virtual interactive e-learning platform; e-Acharya - an

[39] Sourced from: https://timesofindia.indiatimes.com/blogs/voices/the-road-ahead-for-electronics-manufacturing-in-india/

integrated e-content portal; Baadal - an open source project helping institutes set-up their private cloud; e-Kalpa - creating digital learning environment for design; Vidwan - a premier nationwide database of profiles of scientists/researchers/faculty members and a free and open-source software in education (FOSSEE).

Sector Skill Councils

With the expansion of mobile and internet connectivity reaching the distant corners of the country, it is time to develop strategies using these ICT tools to enhance the skills of the workforce. The **"**National Policy on Skill Development and Entrepreneurship 2015**"** laid out the "Skill India Mission" and envisaged the creation of Sector Skill Councils (SSCs) by the National Skill Development Corporation (NSDC). ICT is one of the priority sectors that have been identified based on the skill gap analysis.

IT-ITeS Sector Skill Council (SSC) NASSCOM is the national standard setting body for IT skills, working in close coordination with the industry body NASSCOM and under the aegis of the NSDC. It is working to accelerate the transformation of the education and skills ecosystem to keep pace with the emerging technologies and emerging landscape of skills. According to the **NASSCOM "FutureSkills"** programme, a massive disruption is facing the IT-ITES industry. Of the 4.5 million people employed in the industry today, 1.5 -2 million are expected to require reskilling in the next 4-5 years. Only an industry-driven learning ecosystem can fulfill this massive requirement. Hence, the NASSCOM FutureSkills programme was launched on 19th February 2018 in the presence of senior industry leaders and government officials. The programme aims to reskill 2 million professionals and potential employees and students in the industry over a period of 5 years. To do this, FutureSkills portal uses the technology of the future, to create a space where a learner can access content on all the skills of the future. FutureSkills thus focuses on 155+ skills spanning across 70+ job roles in 10 emerging technologies namely artificial intelligence, blockchain, big data analytics, cloud computing, cybersecurity, Internet of Things, mobile tech, robotic process automation, virtual reality and 3-D printing.

The **Telecom Sector Skill Council** (TSSC) is an industry-led apex body, jointly set-up by the Cellular Operators Association of India (COAI), Indian Cellular and Electronics Association (ICEA) and National Skill Development Corporation (NSDC), to ensure the adequate availability of skilled manpower to boost growth and productivity in the telecom sector. This is particularly true given the rise in the adoption of new-age technologies like 5G, Internet of Things, M2M communication, drone technology, big data, cloud computing, ML/AI, and robotics that are growing on the bedrock of telecom. TSSC works with several ministries, skilling bodies, technical institutes with the objective of promoting skills amongst young Indian talent and bridging the manpower demand - supply gap in the India telecom industry.

The contribution of the ICT sector to the GDP has increased from just 1.2% in 1998 to around 7.9% in 2018 and is estimated to provide direct employment to around 3.97 million people and indirect employment to nearly 10 million (MEITY, 2019). The telecom segment of the ICT sector accounted for 3% of India's GDP while providing direct and indirect employment to 4 million people (Mehta, 2020). To fill the employment gap, the Ministry of Electronics and Information Technology launched **the "National Policy on Electronics 2012"** (NPE 2012) aimed at generating employment to around 28 million people at various levels by 2020. The NPE 2012 was directed towards significantly enhancing the availability of skilled manpower in the ESDM sector by focusing on augmenting post graduate education. Policy objectives focused on the following: (i) enhancement of the number of graduates and other skilled manpower, especially women, by suitably increasing capacities in colleges/ITI and polytechnics through public and private sector investment, (ii) creation of capacities within academic institutions to enhance the production of an adequate number of PhD's and post graduates for supporting the growth of the chip design and embedded software and board/hardware design industry in the country, (iii) setting-up of skilled courses and training programmes for electronic design along with hands-on laboratories enabling graduates from other disciplines to migrate to ESDM, (iv) creation of a specialised institute for semi-conductor design, (iv) extending a special manpower development programme for very large-scale integration (VLSI) chip design to include a larger number of colleges and students leveraging the national knowledge network, (v) creation of an institutional mechanism for the faculty development in various ESDM-related subjects (vi) collaboration with national and international institutions for the development of new skills and courseware on the latest manufacturing technologies and products in the ESDM sector.

Later in 2014, the MEITY launched the "**Visvesvaraya PhD Scheme for Electronics and IT**" with an objective to enhance the number of PhDs in Electronics System Design and Manufacturing (ESDM) and the IT/IT Enabled Services (IT/ITES) sectors in the country. The Cabinet Committee on Economic Affairs (CCEA) approved the scheme for a period of nine years with a total estimated cost of INR 466 crore. That same year in November, the MEITY also introduced the **"Financial Assistance Scheme for setting up of Electronics and ICT Academies".** The objective of this scheme was to set-up seven electronics and ICT academies as a unit in premier academic institutions for faculty/mentor development/upgradation to improve the employability of the graduates/diploma holders in various streams, through active collaboration of states/UTs with financial assistance from the central government. Each electronics and ICT academy aims to provide specialised training to the faculties of the engineering, arts, commerce & science colleges, polytechnics, etc., by developing state-of-the-art facilities. Under the scheme, the following seven electronics and ICT academies have been set-up: NIT Patna (Bihar), IIITDM Jabalpur (Madhya Pradesh), NIT Warangal (Telangana), IIT Guwahati (Assam), IIT Kanpur (Uttar Pradesh), IIT Roorkee (Uttarakhand) and MNIT Jaipur (Rajasthan). The ministry had set-up two ICT Academies at Tamil Nadu and Kerala earlier. The total outlay of the scheme was originally INR 147.48 crore with a duration of 5 years. The scheme was later extended to 31st March 2022 with a revised outlay of INR 87.69 crore (MEITY, 2022). Further, MEITY offers internship opportunities for Indian students from recognised universities under its "Digital India Internship Scheme 2022". Under this scheme, selected students get to work for a limited time period on information technology projects with the central government. This not only benefits the student community but also helps in enriching the management and implementation of government schemes and programmes (MEITY, 2022). Though India has showcased its talent on building supercomputers at low cost, there is a need to further enhance its capacity and meet its requirements. The Government of India launched the **"National Supercomputing Mission"** (NSM) in 2015 with the plan to connect R&D institutions and academic institutions in the country using a supercomputing grid with more than 70 high performance computing facilities, spread over the period of seven years. This will empower scientists and researchers with state-of-the-art supercomputing facilities and enable them to conduct cutting-edge research in their respective domains. It also aims to minimise redundancies and duplication of efforts and optimise investments in supercomputing. The estimated cost of this mission is INR 4,500 crore (IBEF, 2022). NSM is being implemented and steered jointly by the Department of Science and Technology (DST) and Department of Electronics and Information Technology (DEITY). So far under Phase 1 & Phase 2, a total 15 systems with computer power of 22 Petaflops (PF) have been built. Recently, NSM has deployed "PARAM Ganga", a supercomputer at IIT Roorkee on 7th March 2022 with a supercomputing capacity of 1.66 Petaflops as a part of phase 2. Large parts of the components used to build this system are manufactured and assembled in India along with a software stack developed by the C-DAC (Centre for Development of Advanced Computing) as a part of the Make in India initiative (IBEF, 2022). The C-DAC is a premier scientific research organization operating under the MEITY. Focused on advanced computing and software development, the C-DAC plays a crucial role in realisation of the vision of Atmanirbhar Bharat. It has been contributing to the NSM by enabling the manufacturing of systems and components of high-performance computing in India. The contribution of the C-DAC under the NSM shall be a stimulus towards the development of components in advanced technology areas by MSMEs in India.[40]

The Ministry of Science and Technology, in its latest **"Draft Science, Technology, and Innovation Policy 2020" (**Draft STIP 1.4 Dec 2020), lays down a roadmap for leveraging ICT for skill development. The Draft STIP explicitly states that "consortiums will be developed for the creation of new online courses, simulations, virtual and remote labs for enabling immersive experiential learning. A library of virtual resources will be developed through community participation for remote areas. National institutes with advanced lab facilities will be invited to develop such resources and make them available to others. Virtual reality repository can also be developed for this purpose. The repository will be supported with interactive tools, viz. open-source collaborative development platform inviting data visualisation, data presentation, data analytics, AI, etc., for easy access."

Furthermore, the **"New Education Policy (NEP) 2020"** focuses on various facets of education including the integration of ICT. It promotes use of ICT in aiding teachers, bridging the language barrier, creating digital libraries and facilitating a technology-based platform for teacher-training. The policy also highlights the significance of ICT in the promotion of interdisciplinary research and innovation and to improve teaching and enhance the learning, assessment, planning and administration of education. Lastly, it acknowledges the challenges arising from AI and calls for investment in digital infrastructure and online learning platforms (Alam, 2021).

Skill enhancement is a continuous process which requires regular skill upgradation. Exploring the Public Private Partnership (PPP) Model can also ensure a better skilled workforce supply and the need to reposition technical and vocational education and training (TVET) for the development of high-quality skilled workers and knowledge workers. In any country, skills and knowledge are considered to be driving forces for economic growth and social development. It has been observed that the countries

[40] Sourced from: https://www.cdac.in/index.aspx?id=pk_itn_spot1241

with higher levels and better standards of skills and knowledge adjust more effectively to the dynamic challenges and opportunities in the national as well international job markets. India is one of the youngest nations in the world with more than 62% of its population in the working age group (15-59 years), and more than 54% of its total population below 25 years of age. In fact, during the next 20 years the labour force in the industrialised world is expected to decline by 4%, while in India it will increase by 32% (Ministry of Skill Development and Entrepreneurship, 2015). This poses a formidable challenge and a huge opportunity to reap this demographic dividend which is expected to last for the next 25 years. Therefore, India needs to equip its workforce with employable skills and knowledge so that they can contribute substantially to the economic growth and development of the country.

ICTs are rapidly spreading in adoption and accessibility across nations, sectors and organizations. At this rate, the ICT revolution will continue to drive competitiveness and transform sectors while presenting future policymakers with unprecedented new tools for development. The dynamic nature of the sector also raises concerns among policymakers about the adaptability of legacy infrastructure and regulatory frameworks to support the change.

In the words of former WTO Director-General, Mr Renato Ruggiero, "Information and knowledge, after all, are the raw material of growth and development in our globalised world" (WTO, 1997). ICT policies have come to be accepted as critical components of broader development policy initiatives (Mansell, 2010). There is a clear interest and drive on part of the Government of India to harness ICT for inclusive and sustainable development. Efforts have been made to support the ICT sector through policies and projects across the country, but their implementation has been riddled with challenges. These challenges need to be overcome in order to put India's ICT centric innovation ecosystem on a path to success. ICT pervades all sectors of the economy, and it needs to be systematically integrated into the overall vision and strategy for the development of the nation. Mainstreaming ICT into development thinking and practice can help capture its vast potential (Hanna, 2003). The focus should be on developing national policies and frameworks that can unleash the benefits of ICT while mitigating the risks of data theft and cyber-crimes. Studies (Agarwal & Maiti, 2019, Maiti et al., 2019) suggest that fostering well-being through digitalisation and technology as such is not enough. Policymakers need to ensure its co-evolution and complementarity with country-specific factors. Finally, regulations that stifle change need to be adjusted or removed (Pilat, 2004) and the government should promote productive investment and foster market conditions that reward innovation and the successful adoption of ICT in every aspect of the economy.

6. Results and Analysis

Results and Analysis

This chapter sets out to analyse the results of the ICT SSI Survey. It uses a combination of univariate and multivariate analysis which provides a strong empirical foundation. The frame of analysis can be divided into the following sections. Firstly, the characteristics of the survey are described in terms of the composition of the sample and its respondents. This is followed by a comprehensive analysis of the relationships/linkages between the actors of the system. This then leads to the elucidation of the barriers that exist within the ICT system of innovation, and those that are most predominant for each actor group. This is also linked to the question of how successful existing policies are at highlighting either the convergence or divergence between the results and what is articulated in government policy. With this in mind, this chapter aims to highlight the avenues that need attention within the IICTSSI.

6.1 Descriptives

The composition of the actors in the IICTSSI Survey has been detailed in the "Survey Methodology" section. In this section, the characteristics of the IICTSSI Survey that are described in terms of the composition of the sample and its respondents will be discussed. Table 11 below shows the actor distribution and response rate.

TABLE 11: IICTSSI - Convenient sample, data collected and response rates

Firm			Non-firm				Total Number of Non-Firm Actor			Total
Industry			Government	Knowledge based institution	Intermediary	Arbitrageur				
Sample	Data collected	Response rate	Data collected				Sample	Data collected	Response rate	
187	**73**	**39.04%**	**16**	**81**	**84**	**50**	**200**	**231**	**115.50%**	**304**

The overall response rate of the ICT survey is 79%. As seen in Table 11 above, the response rate of industry is 39% while the response rate of non-firm is 116% out of which intermediaries and KBIs together account for 71% of data collected in the non-firm category, followed by arbitrageurs at 22%. With only 16 responses, the government accounts for the least number of responses recorded under the survey.

Figure 8 below summarises the distribution of respondents by actor group. The composition is 28%, 27%, 24%, 16%and 5% from intermediaries, KBIs, industry, arbitrageurs, and government, respectively.

FIGURE 8: Actor distribution of respondents

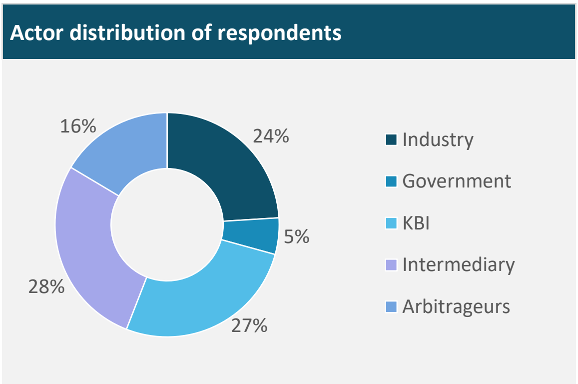


Figure 9 below shows that out of the 73 firms surveyed, 67 are domestically owned and only 6 are foreign-owned firms.

FIGURE 9: Ownership structure of firms

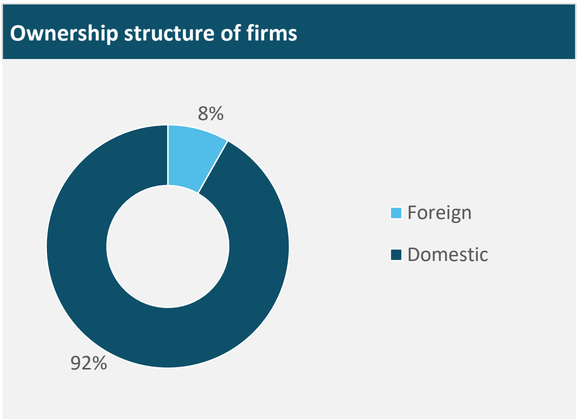
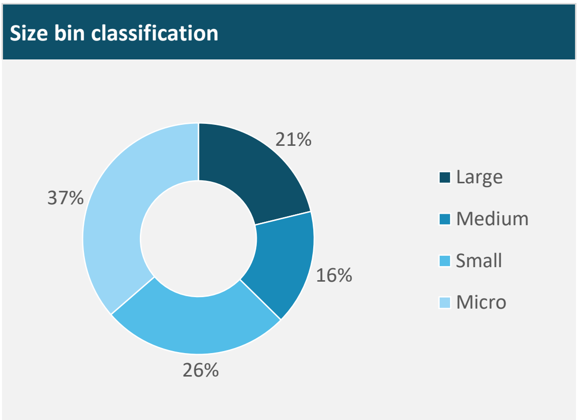


Figure 10 below shows the size bin classification of the firms surveyed. It is important to know the size of firms that participated in the survey as it can determine the level of innovation, internationalization and adoption of emerging technologies, etc. It can be seen from the figure below that the majority of firms surveyed belonged to the 'Micro' size category (36%), followed by 'Small' (26%) and 'Large' size firms (21%). 'Medium' size firms constituted the least percentage (16%) of total firms surveyed in the ICT sector.

FIGURE 10: Size classification



The following figures depict the distribution of respondents by affiliation for each actor group. Figure 11 shows that the industry actor group is made up of 69 'Firm' (95%) and 4 'Firm OBM' (5%). Figure 12 depicts KBI affiliation comprising universities and public and private research institutes, the majority being universities. Subsequently, Figure 13 shows that intermediaries are mostly represented by academic incubators at 77%, followed by industry associations, corporate/private incubators, government incubators and others. Arbitrageurs are composed of banks, angel networks and venture capital while the government comprises both central and state governments, with majority representation from central government agencies. This is outlined in Figure 14 and 15, respectively.

FIGURE 11: Industry – Affiliation

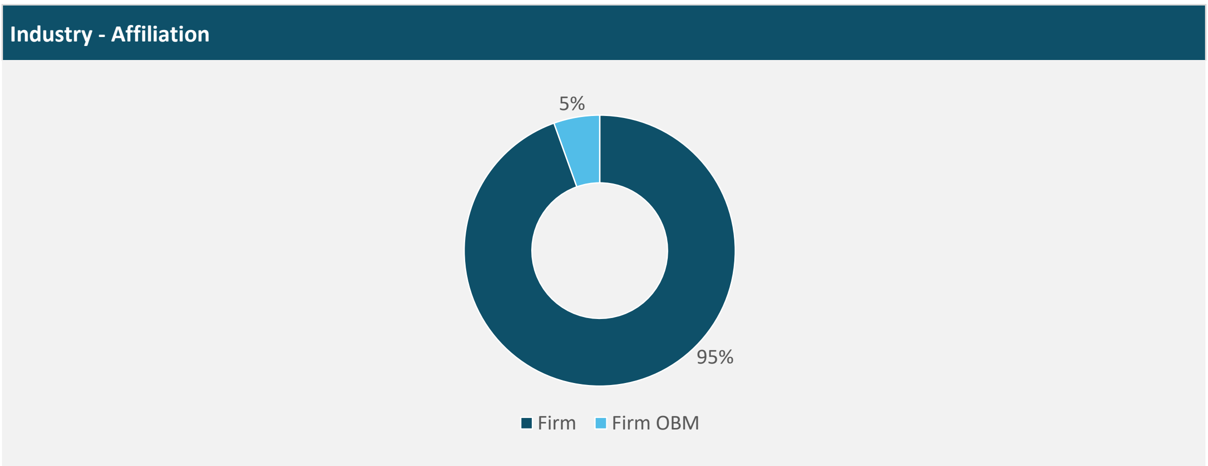


FIGURE 12: **KBI – Affiliation**

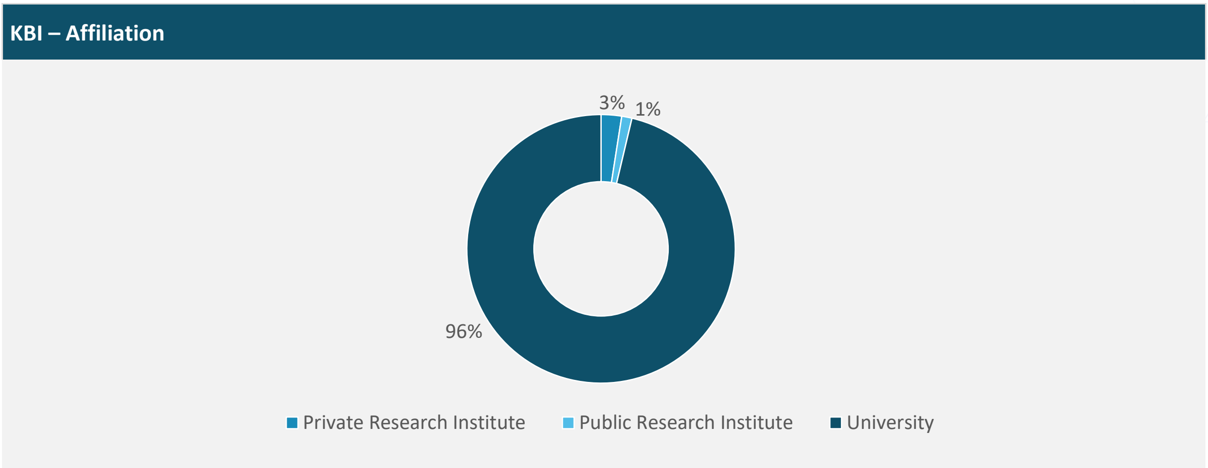


FIGURE 13: **Intermediary – Affiliation**

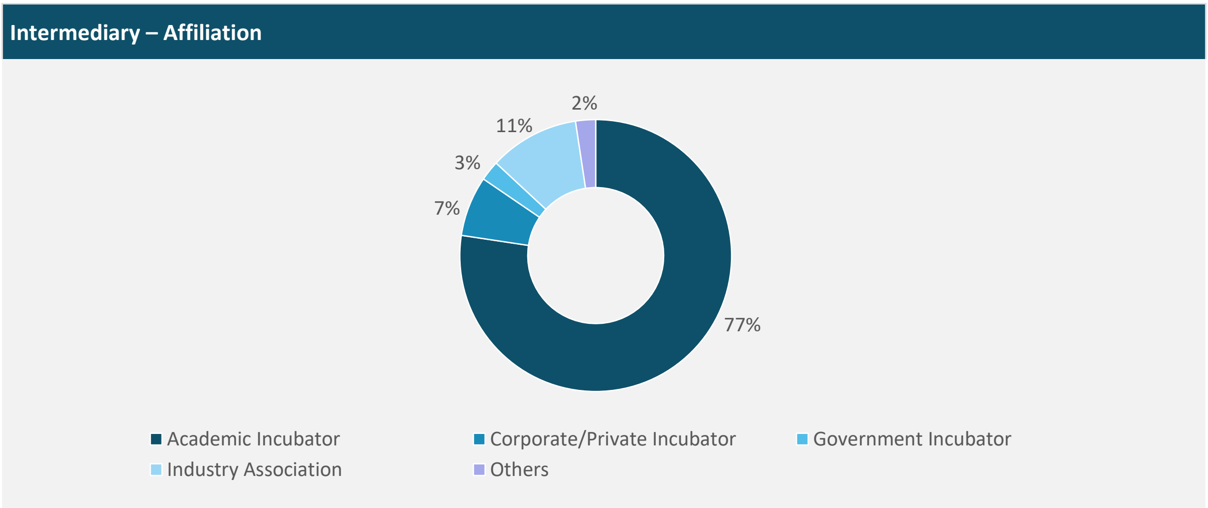


FIGURE 14: **Arbitrageur – Affiliation**

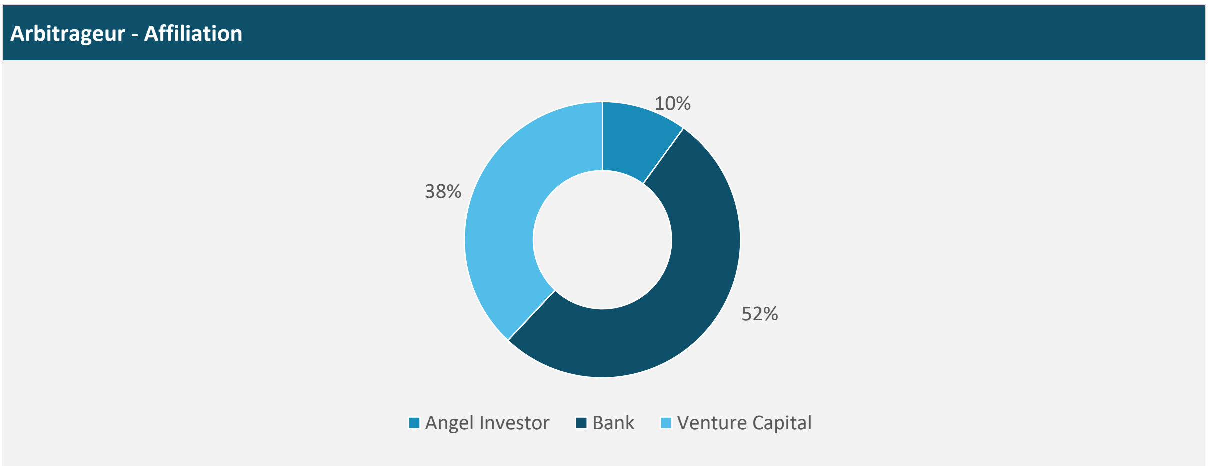
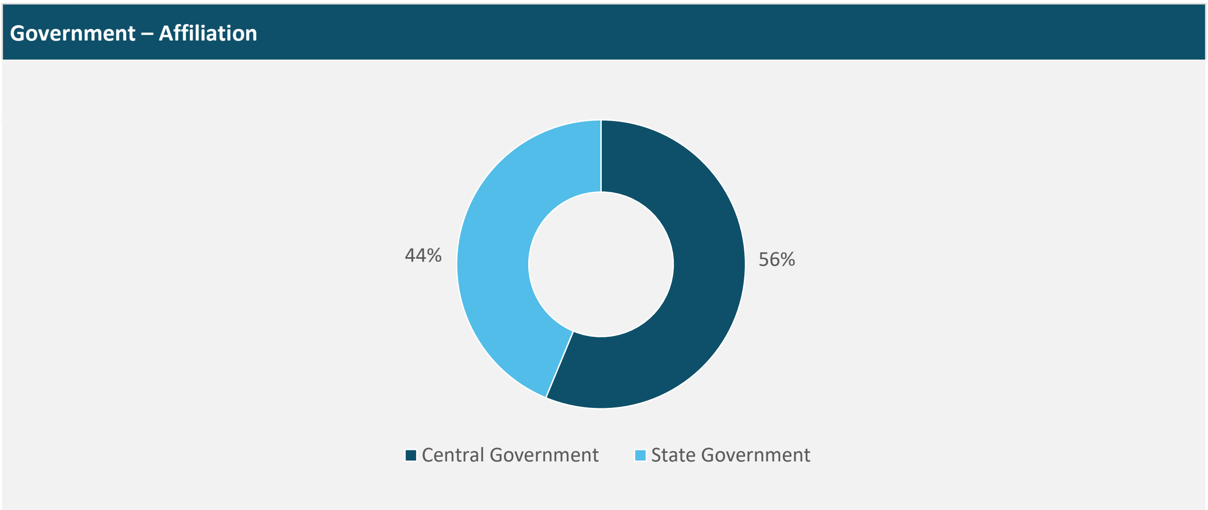
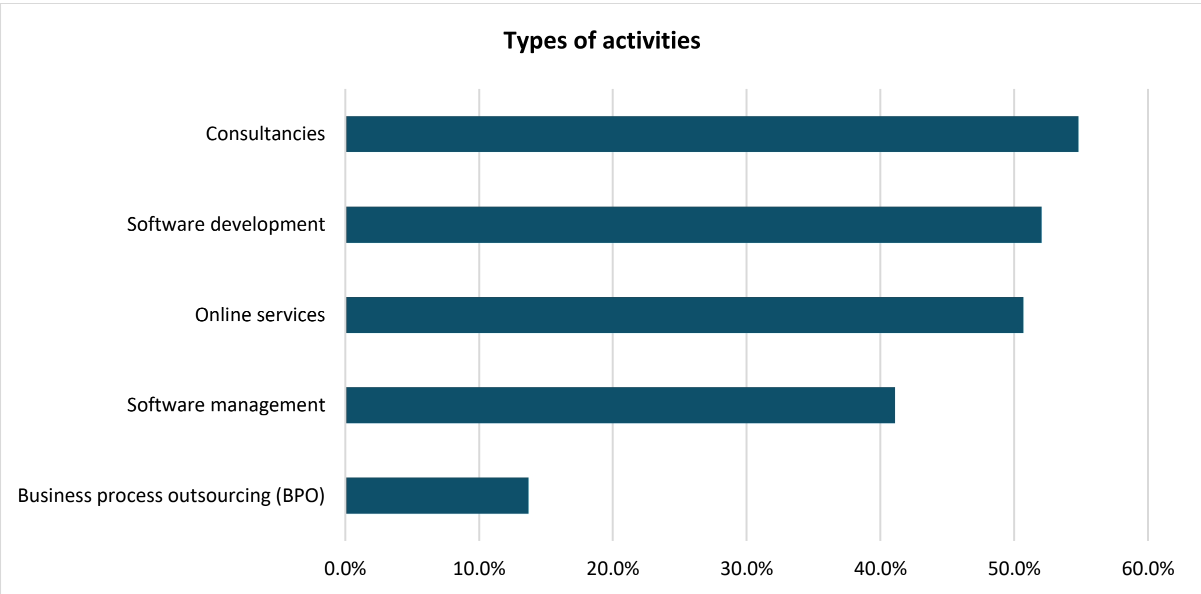


FIGURE 15: Government – Affiliation



It is important to get further clarity with respect to the industry actors in order to better elucidate the data in this report, particularly as the majority of innovation takes place at the firm level. Figure 16 below depicts the type of activities of the firms surveyed.

FIGURE 16: Types of activities of firms surveyed.



As shown in the figure above, 55% of the firms surveyed are consultancy firms, 52% are software development firms, 51% render online services, 41% are into software management and the remaining 14% are involved in business process outsourcing.

6.2 Linkages

Before the issue of the linkages between the actors in the IICTSSI is brought to the fore, it is important to reiterate the importance of linkages from the perspective of the SSI. For instance, in their critique of the linear approach to innovation, Edquist and Hommen (1999) stress the importance of interactive learning and innovation networks, for which linkages between actors are crucial (Oyelaran-Oyeyinka, 2005). Cavalcante (2011) articulates that interaction between agents through formal and informal linkages can take the form of: joint research and publications, personnel exchanges, patents and licenses, the purchase of equipment, or the transfer of technologies or methods. In this light, the analysis conducted is twofold:

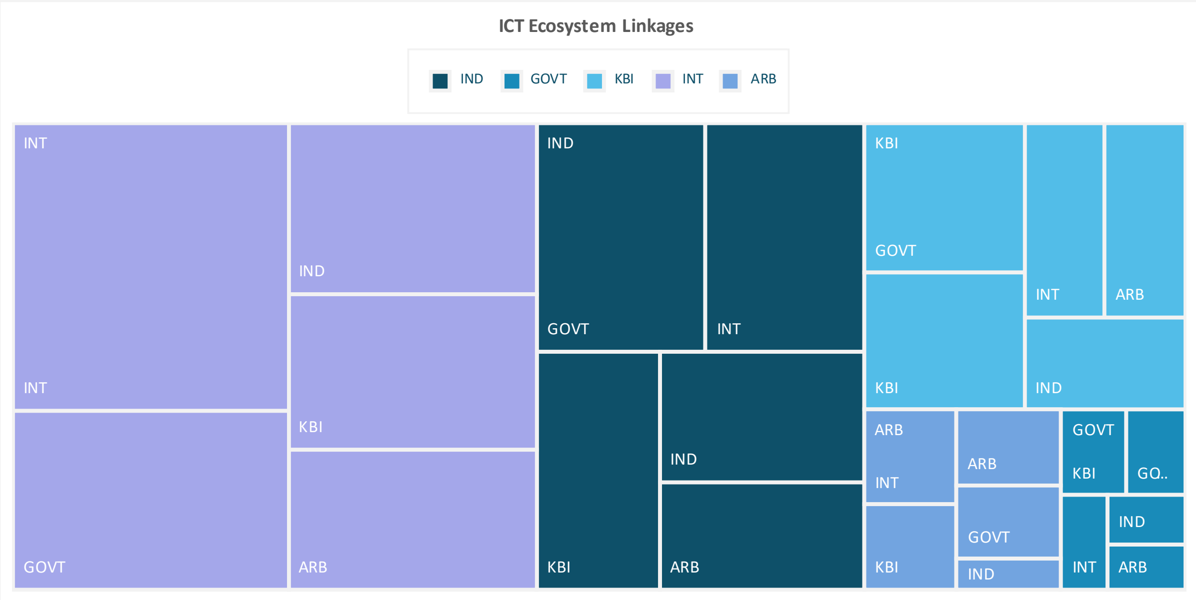
an understanding of the type of relationships that are present and who initiates them.

Type of Linkage

The next point of analysis is to determine which type of engagement occurs when an actor interacts with players in the system. This can be broken down in terms of intra- and inter-relationships. Each respondent was asked to list other actors (industry, government institutions, KBIs, intermediaries and arbitrageurs) their organization engaged with and the respective type of engagement. The types of linkages indicated include. 'Contract buyer', 'Contract supplier', 'Joint patents', 'non-disclosure agreements', 'Trademarking', 'Joint research', 'Co-publishing', 'Secondments', 'Licensing agreements', 'Procurement contracts', 'Formal meetings', 'Informal meetings', 'Seminars/Training', 'Recipients of funding', 'Recruitment/Placement' and 'Joint ventures'. This chapter highlights both the major and minor intra- and inter-relationships as well as the strategic interactions that are crucial to driving innovation in the SSI. Finally, those interactions that are truncated or missing are highlighted in order to better understand and articulate interventions that need to be undertaken to bolster the SSI.

In general, it can be seen from Figure 17 that most relationships are in proportional terms between the actors in the sectorial system of innovation. Firstly, in order of magnitude, the number of respondents the actors who participated interacted with are intermediary, industry, knowledge-based institutions, followed by arbitrageurs and financial institutions and government. Intermediaries mostly interact with themselves, while industry actors have the lion's share of interaction with the government. Knowledge-based institutions primarily interact with the government and themselves, while financial institutions and arbitrageurs primarily interact with intermediaries and the knowledge-base. Finally, the government mainly interacts with knowledge-based institutions.

FIGURE 17: Ecosystem relationships



Sankey diagrams (refer to Figure 18, 19, 20, 21 and 22 below) have been used to display the types of relationships (intra- and inter-linkages) between the system actors, form the perspective of each actor. The diagram is composed of two distinct sections. The left-hand side of the diagram shows the specific system actors being engaged from the perspective of a selected actor, as well as the number of interactions. This provides an indication of who is connected to whom.

From the right-hand side of the diagram we can see the various types of interactions, as well as the total cumulative number for all actors engaging in these types of interactions. However, the specific number of interactions for each actor are not represented in this visualisation.

Overall, the Sankey diagram offers valuable insights into the complex network of relationships and linkages that exist within a particular sector. It can help identify knowledge and resource flows between actors, thus making it a useful tool for understanding the dynamics of the sector.

6.2.1 Industry

Figure 18 highlights industry intra- and inter-linkages.

Intra-relationships

With respect to industry actors the major intra-relationships are knowledge flows in the form of formal and informal meetings and user-producer relationships in the form of contract buyer and supplier. The ICT sector is divided into the ICT producing sector (ICTPS), ICT using sector (ICTUS) and non-ICT using (NICTUS) sector, with their further division into manufacturing and services sectors. The ICTPS includes producers of IT hardware, communication equipment, telecommunications, and computer services (including software). The distinction between the ICTUS and NICTUS was made on the basis of the level of ICT intensity. Practically no industry can however be classified as a non-ICT industry, every industry uses a bit of ICT directly or indirectly. Theoretically, an industry is defined as non-ICT if the ICT intensity is less than one third of the national average.

Knowledge transfer through formal and Informal meetings takes place in the form of B2B platforms and conferences and exhibitions such as India Telecom ICT Expo (IT and Telecom Show), Gates India ICT Channel Summit, and Semicon India, etc.

Formal meetings contribute to the process of sharing information, exchanging and developing ideas, as well as expressing disagreement, and managing conflict (Shasitall, 2022), however this mechanism indicates that there is a structured approach with a focused agenda. Whereas informal communication is crucial for idea generation and the timely transmission of information (McAlpine, 2017), the combination of both formal and informal channels of communication greatly boost innovation (Grimpe and Hussinger, 2008).

Infosys Innovation Network (IIN) is an excellent example of industry-startup collaboration to encourage innovation. It is a partnership between emerging technology startups (dealing with AI, cybersecurity, automation, data management, augmented/virtual reality, blockchain and IoT) and Infosys to provide innovative services to the clients. IIN also helps these startups scale, get certified and be enterprise-ready to meet the organizational need and provide clients with a constant stream of highly competitive and innovative solutions.

Inter-relationships

When examining the collective inter-relationships with other actors of the system, the most prominent interactions are in terms of formal and informal meetings, seminars and training, joint research as well as recruitment and placement.

For example, in 2018, Microsoft, in collaboration with the Data Security Council of India (DSCI) launched a programme called “CyberShikshaa” to build a strong pool of diverse cybersecurity talent in the country. In October 2022, Microsoft announced expansion of this programme in association with the DSCI, Tata STRIVE, and ICT Academy to reach 45,000 women and underserved youth with technical skills for careers in cybersecurity and provide internships or job opportunities for 10,000 learners by 2025[41]. In November 2022, the ICT Academy, an initiative of the Information Technology and Digital Services Department, Government of Tamil Nadu, announced its partnership with ServiceNow, a leading digital workflow company, to take its digital training and skills programme to 1,000+ ICT Academy partner institutions to benefit educators and students with digital skills[42].

Knowledge dissemination through seminars and trainings, is evidenced by fora such as Semicon India 2022[43], organised by the “India Semiconductor Mission”, MEITY in partnership with industry and industry associations, which aims to make India a global hub for semi-conductor design, manufacturing and technology development. Participants included a mix of startups, academia and global industry leaders. It acts to demonstrate the government’s collaborative approach towards pushing India’s semi-conductor and electronics manufacturing ambitions. The conference serves as the formal launch pad of India’s semi-conductor strategy and policy which envisions making India a global hub for electronics system design and manufacturing. Additionally, there is the National Association of Software and Service Companies (NASSCOM) Annual Technology and Leadership Forum which aims to position itself at the forefront of technology, connect with technology luminaries, take advantage of the NASSCOM ecosystem, learn what exactly is needed to move innovative solutions through deep dive sessions and master classes.

At the level of the knowledgebase, an example of industry – KBI linkages and knowledge transfer is seen in the example of Microsoft Garage which partnered with the IIIT Hyderabad[44] to accelerate learning on quantum computing. A series of lectures are offered as a pool elective for B.Tech and M.Tech students, the objective being to provide the scholars practical experience in quantum computing and

[41] Sourced from: https://news.microsoft.com/en-in/microsoft-expands-cybershikshaa-to-accelerate-cybersecurity-skilling-opportunities/
[42] Sourced from: https://www.cxotoday.com/press-release/ict-academy-collaborates-with-servicenow-to-empower-indian-educators-students-with-digital-skills/
[43] Sourced from: https://www.semiconindia.org/
[44] Sourced from: https://news.microsoft.com/en-in/microsoft-garage-iiit-hyderabad-quantum-computing/

quantum algorithms with access to the Microsoft Quantum Development Kit and Microsoft Q#.

Quantum computing is poised to alter the world's economic, industrial, academic, and societal landscape. Quantum computers have the capacity to solve complex problems that would otherwise take billions of years for today's computers to solve within weeks, days, and even minutes. This has massive implications for research in healthcare, energy, environmental systems, smart materials, and more. It also creates a need to start building a quantum-ready workforce well versed in quantum computing skills.

The ICT industry has emerged as a major contributor to the Indian economy as well as a provider of employment in the country. Though the Indian ICT industry has been driven by software development services, the trend is changing, and the country is becoming the R&D hub of multinational IT companies. Several India-based multinational IT giants have also set-up their R&D and innovation centres domestically. The government views R&D as essential for the implementation of new initiatives such as "Digital India", "Make in India" and "Startup India". It has also launched new schemes in R&D such as "Impacting Research Innovation and Technology (IMPRINT) India", through which it aims to promote R&D in the emerging areas with a view to providing technological solutions at the level of society, industry, and government. The major thrust areas include: blockchain, data analytics, quantum technologies, Internet of Things (IoT), green computing, artificial intelligence (AI), and perception engineering.

An excellent example of how industry and the knowledgebase have come together is the Indraprastha Institute of Information Technology (IIIT) Delhi which has announced a memorandum of understanding (MoU) with Delhi-based artificial intelligence and machine learning surveillance development firm, Vehant[45.] Under the MoU, five students pursuing graduate and research courses at the IIIT Delhi will be granted a fellowship amounting to INR 10 lakh for two years which can be used for any academic and research purposes. To be sure, Indian institutes offer a range of fellowships in AI and ML research; the Robert Bosch Centre for Data Science and Artificial Intelligence (RBCDSAI) at the Indian Institute of Technology (IIT) Madras, for instance, grants students a fellowship stipend of INR 18 lakh per annum, along with the chance of a one-time grant of INR 30 lakh, to pursue research on developing AI for social improvement causes.

The country is witnessing the emergence of similar initiatives such as Microsoft's "Research Fellows in India", and "Qualcomm's Innovation Fellowship" in partnership with numerous IITs also offering similar AI fellowship opportunities in the field of research and development across India.

This mechanism of scholarships is often linked to Corporate Social Responsibility (CSR) activities of companies. This is doubly beneficial as it provides the recipient with exposure and means to study, and for firms it enables them to build and strengthen relationships with multiple stakeholders (Raghubir et al. 2010), as well as possibly creating corporate value (Barnett, 2007) through monitoring possible new avenues of technological development.

Generally, the knowledgebase is seen as a source of skilled human capital and recruitment that takes place through recruitment offices or placement cells. However, given the need to bolster R&D, Tata Consultancy Services (TCS) has indicated it would hire computer science PhDs from the Indian Institutes of Technology (IITs) without interviews[46].

[45] Sourced from: https://www.techcircle.in/2022/07/27/iiit-delhi-signs-mou-with-vehant-to-offer-fellowships-in-ai-ml-research

[46] Sourced from: https://economictimes.indiatimes.com/jobs/tcs-to-hire-phds-from-iits-without-interviews/articleshow/3871327.cms?from=mdr

BOX 1: WIRIN – Wipro-IISc Innovation Network (Industry - KBI linkage)

Objective

A hybrid model consortium involving industry, academia, startups and funding agencies to advance research and development in emerging technologies and also advantage the industry partners in autonomous systems and robotics

Approach

The WIPRO IISc Research and Innovation Network (WIRIN) [47] is a collaboration since 2017 between WIPRO, a multinational Indian IT consulting and services company, and the Indian Institute of Science (IISc), a premier research organization on AI-driven autonomous vehicles.

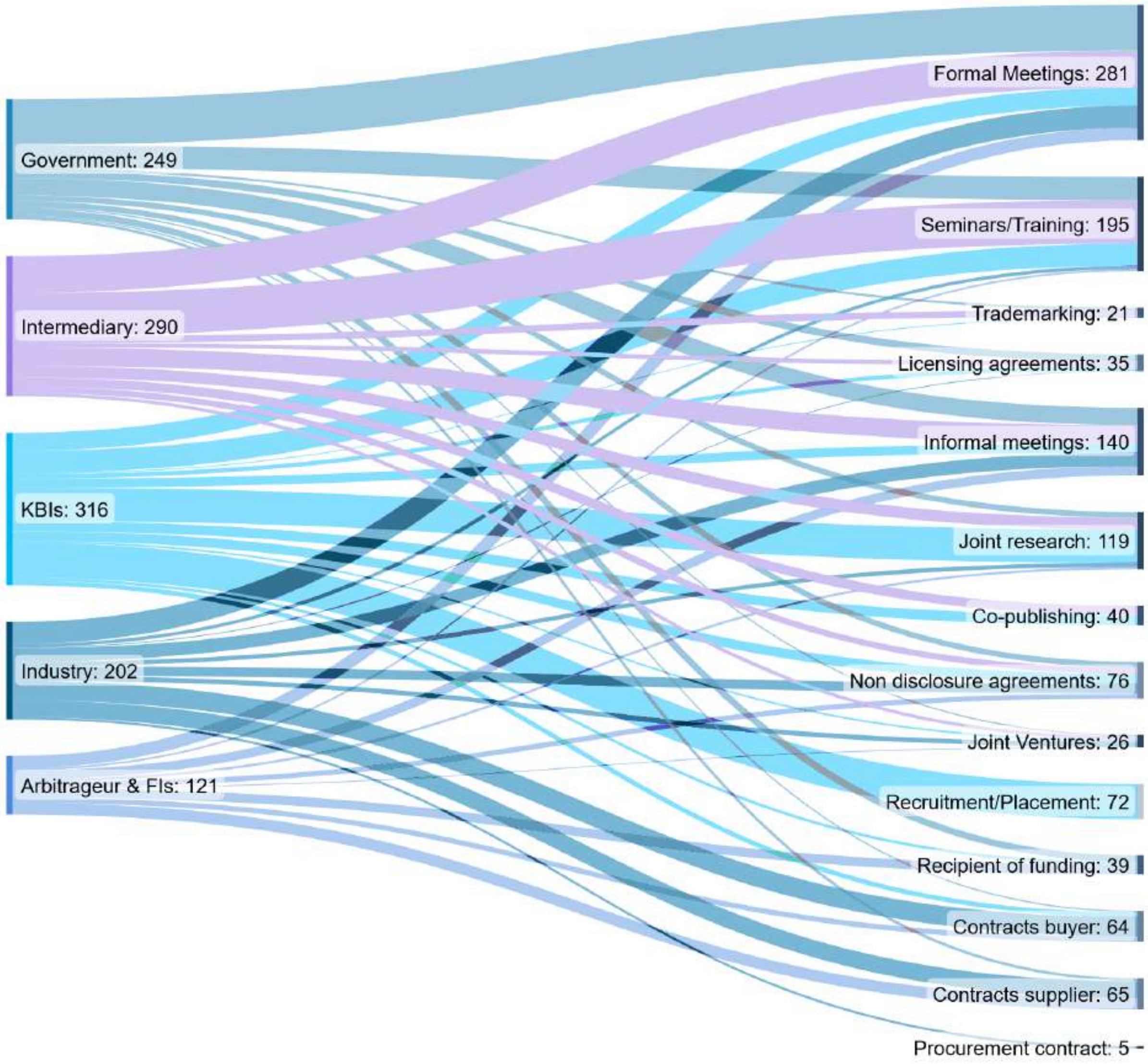
WIRIN has strong emphasis on emerging technologies, disruptive designs and the manufacturing of autonomous systems, imaging, image processing and computer vision, AI, machine and deep learning algorithms, data science and analytics, security and smart materials. WIRIN innovation labs at the IISc offers a facility for software development for vehicle simulators and autonomous electric vehicles using national data sets and the WIRIN Centre of Excellence. Besides annual funding of US$ 500,000 for the discovery, definition and execution of WIRIN projects, including the WIRIN Innovation Lab, and fellowships, WIPRO mobilises resources from public and private sector partners such as the National Institute of Design (NID) and the RV College of Engineering (RVCE). Both WIPRO and the IISc are entitled to use, exploit and commercialise the IP developed in the project without any recourse.

Outcomes

WIRIN built a new state-of-art autonomous car, WIPOD, that can change its internal structure according to the needs of the user. The NID led the development of the WIPOD design, user-interface and experience, while the RVCE played a pivotal role in technology development and innovation. The IPs generated from the WIRIN projects are building blocks in developing AI stacks, a collection of software tools, services, and processes that will allow scientists to build better autonomy in the new generation of the WIPOD autonomous vehicle. WIRIN enables open-source national autonomous vehicle data sets (globally accessible to researchers) to advance AI stacks and also fosters and strengthens the flow of information from industry and the IISc. Such information flow will be to the design and development of new products and processes of commercial importance and social value.

[47] Sourced from: WIRIN | Wipro IISc Research and Innovation Network.

FIGURE 18: Industry relationships



6.2.2 Knowledge-Based Institutions

Figure 19 highlights knowledge-based institution intra and inter linkages.

Intra-relationships

The majority of intra-linkages reported by KBIs are formal and informal meetings, seminars/training, joint research and co-publishing.

The levels of communication between KBIs indicate that there is some degree of collaboration taking place between them. Tacit knowledge transfer takes place through national and international fora. For example, the National Conference on Communications (NCC) is a flagship conference in the broad areas of communications, organised every year by the Joint Telematics Group (JTG) of the Institutes of Technology (IITs) and the Indian Institute of Science (IISc). It has become a regular forum for researchers, students and practicing engineers to present and exchange ideas on the latest technological advancements and innovations. The salient features of this conference are pre-conference tutorials, technical paper sessions, plenary talks by experts, and industrial exhibitions. Over the last twenty-eight years, it has witnessed a progressively larger participation of researchers both from academia and industry. The twenty-ninth NCC will be jointly organised by IIT Guwahati, IIT Patna and IIT Ropar.

In a bid to boost cross-functional research, the Indian Institute of Technology (IIT) Delhi and Indraprastha Institute of Information Technology (IIIT) Delhi invited joint research projects from faculty members of both institutions[48]. An external experts committee then selected five projects for seed grants. With the paradigm shift associated with the advent of Industry 4.0 it is clear that there is a convergence of disciplines. This unique collaborative initiative has already brought together faculty members from both the institutes and inspired them to define problems of mutual interest, exchange expertise and foster relationships. The overall objective is to improve the posture of technological innovation and next-generation research.

The externalisation of knowledge in the form of co-publishing is generally associated with National Assessment and Accreditation Council (NAAC) accreditation under the pillar of research innovation and extension, or the National Institutional Ranking Framework (NIRF) under the pillar of research and professional practice.

BOX 2: 5Gi - The 'Made in India' 5G Radio Interface Technology

Objective

India has developed a set of 5G standards, called 5Gi, to facilitate the spread of 5G networks in rural and remote areas of the country.

Approach

The 5Gi standard, also known as Radio Interface Technology, is a local 5G standard developed by India. It is the result of a joint collaboration between IIT Madras, IIT Hyderabad, Centre of Excellence in Wireless Technology (CEWiT) - autonomous research society of IIT Madras, and the Telecommunications Standards Development Society, India (TSDSI) - national telecom standards development organization.

In 2021, the ITU (International Telecommunication Union) and 3GPP approved the 5Gi standard and agreed to merge its specifications with international 5G's standard. 3GPP is the global body that provides standards and specifications for telecommunications technologies. It is the first time that Indian contributions will be included in global standards which is considered a huge win for India as 3GPP rarely approves competing standards to maintain global interoperability.[49] This offers more range at lower frequency then 5G network which works at higher frequency bandwidths.

Anticipated outcomes

The 5Gi standard has been developed for a more cost-effective implementation and wider 5G connectivity. This is a huge step towards building a strong homegrown 5G mobile communications ecosystem in the country.[50].

Inter-relationships

Collective inter-relationships with other actors of the system, the most prominent interactions are formal and informal meetings, seminars and training, joint research, and as recipients of funding.

The knowledgebase has been interacting with industry and intermediaries for the training of the future workforce in skills relevant to the ICT industry while also improving employment opportunities for the youth in India. One example of this is the creation of the "Digital Skills Academy", an initiative of NASSCOM and IIT Madras, to deliver structured IT-ITeS skill programmes through online and classroom trainings. Another example is the TERI School of Advanced Studies (SAS) signing a memorandum of understanding (MoU) with the Cisco Networking Academy (one of Cisco's corporate social responsibility priorities) to address the skills gaps in digital skills towards sustainability. This joint MoU will enable students to leverage the "Cisco Networking Academy" programme skills and knowledge and implement the same in their subject areas of environment, climate change, geo spatial data and other areas related to sustainable development.

From the perspective of knowledge-based interactions with other system actors, to some extent the combination of formal and informal mechanisms of interaction enables the dissolution of organizational rigidities and better exchange

[48] Sourced from: https://timesofindia.indiatimes.com/city/delhi/iit-iiit-tie-up-for-next-generation-research/articleshow/88497732.cms
[49] Sourced from: https://www.6gworld.com/exclusives/can-india-live-up-to-its-6g-ambitions/
[50] Sourced from: https://government.economictimes.indiatimes.com/news/governance/indias-own-indigenously-developed-5g-technology-to-be-deployed-in-rollouts-mos-communication-devusinh-chauhan/93445293

of ideas, which may then be formalised in terms of formal transfer mechanisms like licensing and the acquisition of patents (Jensen and Thursby, 2001; Thursby and Kemp, 2002), joint research (Cockburn and Henderson, 1998) or consulting (Thursby et al., 2007). An example of joint research and licensing agreements is the IIT Madras collaborating[51] with IBM on quantum computing education and research. The collaboration would provide the IIT Madras faculty, researchers, and students access to IBMs quantum systems and tools over IBM Cloud. Other indications of joint research involving intermediaries is GS1 India, a global supply chain standards organization, and Midas Research Lab of the Indraprastha Institute of Information Technology, Delhi, a leading research-oriented academic institute, signing a Memorandum of Understanding (MOU)[52] to create the DataKart Centre of Excellence (DCoE). The aim is to apply artificial intelligence, machine learning and other futuristic technologies to develop tools for image compression, attribute extraction, and for improving the quality of product data in the National Product Data Repository (DataKart).

An example of the knowledgebase working with the government is IIT Jodhpur signing an MoU with the Jodhpur City Knowledge and Innovation Foundation (JCKIF) and RajCOMP Info Services Ltd. (RISL), a Government of Rajasthan undertaking to establish the joint initiative on Artificial Intelligence of Things (AIOT) systems and technology development.

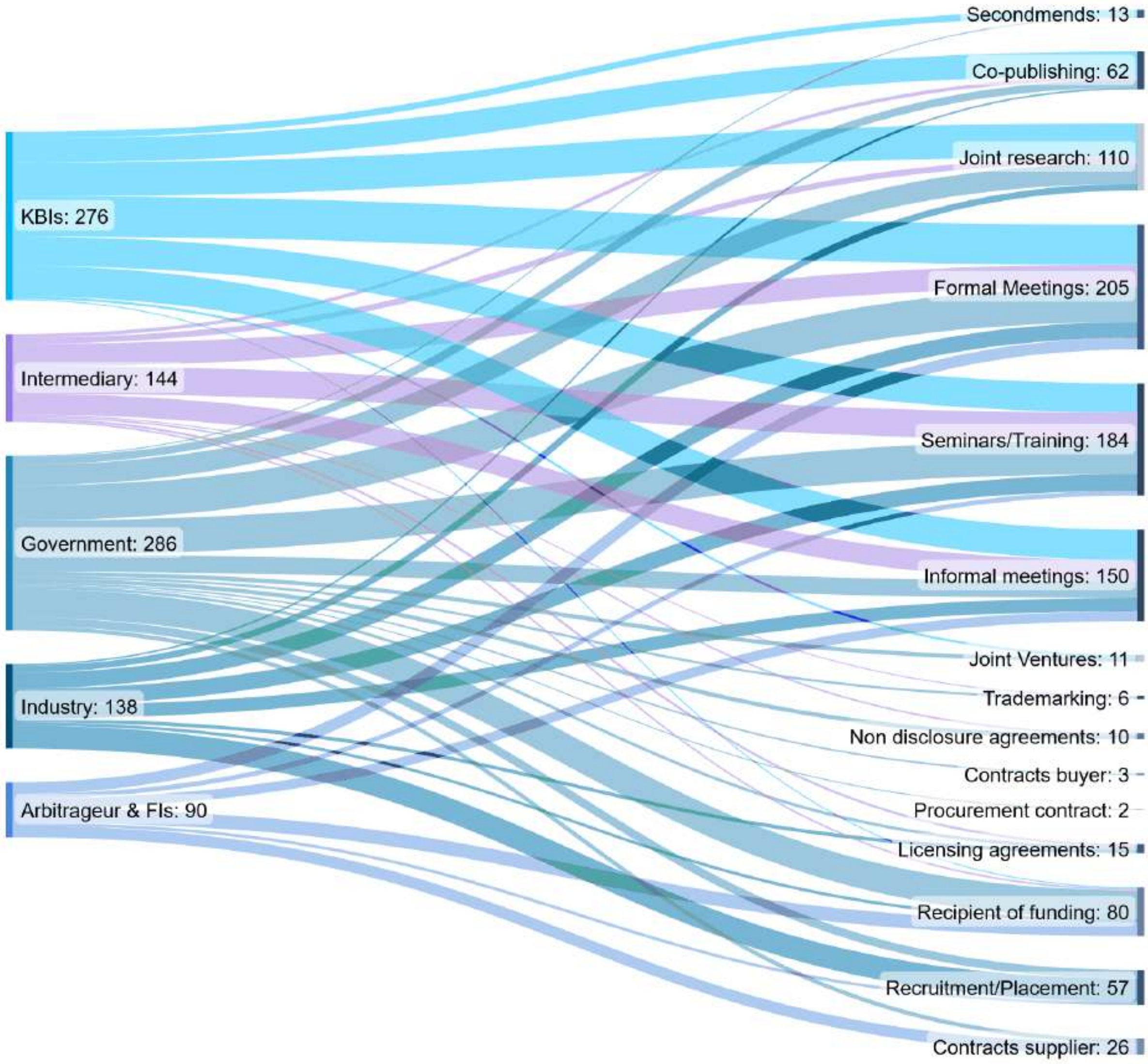
Similarly, with respect to knowledge-based institutions and arbitrageurs and financial institutions, TVS Credit Services Ltd, a non-banking financial company, and the Indian Institute of Technology Madras have signed up an agreement to design and boost innovation programmes and carry out joint research activities. This partnership aims to provide technology solutions in the space of FinTech and data science.

The following examples highlight the flow of funds between knowledge-based institutions and other system actors, namely government and arbitrageurs and financial institutions. The Department of Science and Technology (DST) has funded INR 100 crore for establishing a cognitive computing hub at the Indraprastha Institute of Information Technology (IIIT), Delhi under the "National Mission on Interdisciplinary Cyber-Physical Systems" (NM-ICPS)[53]. The DST is working towards creating a seamless ecosystem for CPS technologies including basic and applied knowledge generation, human resources, technologies, startups, and industry connect. iHUB Anubhuti at the IIIT Delhi will build a strong tripartite collaboration between industries, academia and government agencies and become both an aggregator as well as a custodian of the roadmap in its areas of cognitive computing and social sensing. The hub has been set-up to create a collaboration between industries, academic institutions, and government agencies to innovate and develop data-driven cognitive computing solutions.

Additionally, the SBI and IIT Bombay signed an MoU with a strategic initiative to promote innovation by engaging with startups in the area of FinTech, through funding, procurement and co-innovation under a special window.

[51] Sourced from: https://economictimes.indiatimes.com/tech/information-tech/iit-madras-to-collaborate-with-ibm-on-quantum-computing/articleshow/83120124.cms
[52] Sourced from: https://indiaeducationdiary.in/gs1-india-signs-mou-with-iiit-delhis-midas-research-lab-to-establish-the-datakart-centre-of-excellence/
[53] Sourced from: https://www.livemint.com/education/news/dst-grants-rs-100-crore-for-cognitive-computing-hub-at-iiitdelhi-11630143923094.html

FIGURE 19: Knowledge-based institution relationships



6.2.3 Government

Figure 20 highlights government intra- and inter-linkages.

Intra-relationships

The main intra-linkages reported are formal and informal meetings, seminars and training, joint research and as recipients of funding.

Due to the complexity of policy making, the division of labour between government agencies makes it almost impossible for one agency to dominate the process. Joint efforts involving different agencies are essential as is highlighted by formal and informal communication. Therefore, communication, coordination, and mutual adjustment between these stakeholders and between the stakeholders and the environment against which policy is made is required (Flanagan et al., 2011).

In order to utilise and harness the benefits of cloud computing, the Government of India embarked upon an ambitious initiative in 2013 named “GI Cloud”. The focus of this initiative is to accelerate the delivery of e-services in the country while optimising the ICT spending of the government. The MEITY has centralised the cloud service offerings of major Cloud Service Providers (CSPs) for ease of cloud procurement for the government departments and service offerings are formally communicated to government departments through a centralised platform (MEITY, 2013).

In August 2022, the National e-Governance Division (NeGD), under the MEITY, organised a capacity-building programme for cloud computing targeting government officials at the centre and state levels. This was done to ensure the availability of adequate knowledge and appropriate competencies and skill sets to optimally utilise the benefits of cloud computing in e-governance practices[54].

Other landmark initiatives include the "Digital India" programme, with a vision to transform India into a digitally empowered society and knowledge economy. "Faceless, Paperless, Cashless" is one of the professed roles of Digital India and the promotion of digital payments has been accorded the highest priority by the Government of India to bring each and every segment of the country under the formal fold of digital payment services. The vision is to facilitate seamless digital payments to all Indian citizens in a convenient, easy, affordable, quick and secured manner.

Several activities for the promotion of digital payments have been announced, including setting a target of INR 2,500 crore digital payment transactions in FY 2017-18, through Unified Payments Interface (UPI), Unstructured Supplementary Service Data (USSD), Aadhar Pay, Immediate Payment Service (IMPS) and debit cards.

The MEITY has been entrusted with the responsibility of leading the "Promotion of Digital Transactions including Digital Payments" initiative and is working on various strategies and ideation with multiple stakeholders including banks, central ministries/departments and states, to create an ecosystem to enable digital payments across the country.

The MEITY has undertaken several initiatives to promote digital payments and achieve the targets in a mission mode, including but not limited to:

a. Digital payment transaction targets have been assigned to central ministries with high citizen touch points, and public and private sector banks to achieve the target as announced in the Budget Speech for FY 2017-18.

b. Training and workshops on digital payments awareness have been conducted and planned with several ministries.

c. Promotional material on digital payment including information, education and communication (IEC) is being shared with stakeholders to create awareness and sensitisation.

d. A digital payment dashboard has been created to track and monitor the progress of digital transactions achieved by banks.

e. A promotion and awareness approach framework on digital payments has been shared with banks.

f. BHIM cash back schemes for merchants.

g. BHIM Aadhaar merchant incentive schemes.

h. BHIM referral bonus schemes for Individuals.

Other initiatives and cross governmental areas of collaboration include the MEITY collaborating with the Ministry of Finance on developing a strategy for block chain/crypto-currency technologies.

Beyond policy, the Centre for Development of Telematics (C-DOT) and Centre for Development of Advanced Computing (C-DAC) signed an MoU at SemiconIndia 2022 [55] to boost indigenous telecom and ICT technological design and development.

An example of funding flow between government entities is the Medical Electronics Incubation Centre at the IIT Patna. In 2014, MEITY approved a project for development of product and IP creation in the Electronics System Design & Manufacturing (ESDM) industry with a focus on medical electronics at a total estimated cost of INR 47.10 crore including a Grant-In-Aid of INR 22.10 crore from the MEITY. The State Government of Bihar contributed INR 25 crore in the project. The incubation facility developed through the MEITY and state government partnership has incubated over 60 startups and given INR 6 crore in seed funding to date[56]. The primary objective of this is to promote innovation and entrepreneurship with the aim to identify, nurture and translate technological ideas and innovation in the broad area of the ESDM sector with a focus in medical electronics.

Inter-relationships

On review of the inter-relationships between government and other system actors, the most prominent types of interaction are formal meetings, seminars and training, joint research, as recipients of funding and co-publishing.

Multi-stakeholder processes in policy craft are crucial in bringing together major stakeholders to participate in formal communication, decision finding (and decision-making) on a particular issue (Hemmati, 2002). Häring et al., (2009) highlight the view of several authors in defining different types of participation in multi-stakeholder processes (Biggs, 1989; Lilja and Ashby, 1999; Pretty, 1995; White, 1996). Probst and Hagmann (2003) described linkages between different social actors, according to varying degrees of involvement in and control over decision-making in the relationship. ''Different actors collaborate and are put on an equal footing, emphasising linkage through an exchange of knowledge, different

[54] Sourced from: https://opengovasia.com/india-builds-cloud-computing-capacity-building/
[55] Sourced from: https://www.cdac.in/index.aspx?id=pk_itn_spot1277
[56] Sourced from: https://iciitp.com/

contributions and a sharing of decision-making power during the innovation process" (Probst and Hagmann, 2003: p. 6).

The benefits of multi-stakeholder processes include:

- **Quality**: Stakeholders add specific experiences and knowledge of issue areas that are not easily accessible to others.
- **Credibility**: Multi-stakeholder processes include groups that do not represent the same interests. Likelihood of impact and implementation: Being part of a multi-stakeholder process, and thus partly responsible for its outcomes, can increase people's commitment to the outcome and enhance their efforts to communicate and implement them.
- **Societal gains**: Democratic participation, equitable involvement and transparent mechanisms of influence create successful communication across interest groups and competitors. Consensus building and joint decision-making can increase mutual respect and tolerance and lead societies out of deadlock and conflict on contentious issues.

With this in mind, it is crucial to highlight the key role of industry associations in working with the government to support policy making as they can convey the views of their members and address concerns, if any. As such NASSCOM plays a crucial role in building an enabling policy framework for the growth of the ICT sector. Since its inception, NASSCOM has focused on evidence-based policy advocacy that provides an unbiased perspective to policy makers. With inputs from multiple stakeholders across segments that comprise the membership, NASSCOM is able to collate and distill information to present various perspectives in an unbiased way.

Over the years, NASSCOM has enabled several changes in key policies in India to support the growth of the industry. It has built a symbiotic relationship with the Government of India on key issues relating to this sector and strives to be a trusted industry partner in policy framing and review.

Knowledge dissemination in the form of seminars and training emerges at multiple levels. In 2016, the Department of Electronics and Information Technology launched a scheme named "Support for International Patent Protection in E&IT" [57]. Its aim is to provide financial support to MSMEs and technology startup units for international patent filing to encourage innovation and recognise the value and capabilities of global IP along with capturing growth opportunities in the ICT sector. In addition, it will sensitise, create IP awareness and disseminate the scheme among stakeholders; a second component of the scheme has been proposed to support IPR awareness.

A pace with this, the MEITY inaugurated a world class skills development centre at Dixon Technologies, Noida[58] to offer full-time skills training and courses to 1000 candidates under the MEITY's "Scheme for Skill Development in the Electronics System Design and Manufacturing (ESDM) Sector". Dixon Technology is a beneficiary company under the "Production Linked Incentive (PLI) Scheme" of the MEITY. Through this initiative, the Government of India is helping the industries to scale-up their manufacturing capacities as well as support industry in developing skilled manpower for its production requirements. After the training of the candidates, they will get the skill certification from the Electronic Sector Skill Council of India (ESSCI).

Highlighting the crucial importance of research for the sector, "IMPacting Research INnovation and Technology (IMPRINT)" is a first-of-its-kind, Pan-IIT and IISc joint initiative to develop a (a) new education policy, and (b) roadmap for research to solve major engineering and technology challenges in selected domains needed by the country. The core objective is to enable, empower and embolden the nation for inclusive growth and self-reliance. To date, under the aegis of IMPRINT', seven projects are under implementation with partial funding from the MEITY (MEITY, 2022).

Other initiatives include collaboration between government and intermediaries. NASSCOM, the MEITY and Government of Andhra Pradesh joint partnership has launched the Centre of Excellence on IoT and AI59 at Andhra University Campus in Visakhapatnam aimed at promoting innovation in emerging technologies of the IoT, AI, robotics, etc. The centre aims to advance the Government of India's "Digital India" vision through the provision of open labs and infrastructure to create and validate solutions from design to prototype to democratise innovation. It also promotes entrepreneurship by providing an incubation facility for peer-to-peer learning with the benefit of an industrial environment. Startups in the state are also expected to benefit through the launch of the new centre with newer opportunities in areas of their development, mentorship, funding, and the adoption of their solutions in the industry.

Many of the aforementioned initiatives have highlighted funding from multiple sources. However, an example of

[57] Sourced from: https://www.meity.gov.in/content/sip-protection-electronics-it-sip-eit-scheme
[58] Sourced from: https://theeducationpost.in/meity-launches-skill-training-under-esdm-scheme/
[59] Sourced from: https://indiaai.gov.in/news/meity-nasscom-govt-of-andhra-pradesh-launch-coe-of-iot-ai-in-vizag

targeted funding for the sector is the Karnataka Information Technology Venture Capital Fund (KITVEN Fund) which is a state and central government financial institution-backed Venture Capital Fund (VCF) operating in the State of Karnataka since 1999. The fund received subscription from premier institutions like Karnataka State Industrial and Infrastructure Development Corporation Limited - KSIIDC, Karnataka State Financial Corporation - KSFC, Small Industries Development Bank of India - SIDBI, Karnataka Bio-technology & Information Technology Services (KBITS), etc.

Similarly, the Karnataka Semiconductor Venture Capital Fund (KARSEMVEN Fund) is a SEBI registered Venture Capital Fund with a corpus of INR 92.95 crore. The fund proposes to undertake investments in companies catering to semi-conductor ESDM, embedded systems and other allied sectors within the State of Karnataka. The fund received commitment from state and central government firms/ institutions/ banks like Karnataka Biotechnology & Information Technology Services (KBITS), Small Industries Development Bank of India (SIDBI), CanBank Venture Capital Fund (from Electronic Development Fund, Govt. of India), Life Insurance Corporation of India (LIC), Union Bank of India (UBI), Canara Bank, Punjab National Bank, Andhra Bank and KSIIDC Ltd. The KARSEMVEN Fund undertakes investment in the range of INR 2 crore to INR 5 crore per company during the initial stage which can be enhanced up to INR 9.2 crore per company at a later stage in the form of follow-on investment.

A clear example of the general codification and strategic transmission of knowledge is the "National AI Portal of India (INDIAai)", which is a joint initiative by the MEITY, National e-Governance Division (NeGD) and NASSCOM and has been set-up to prepare the nation for an AI future. The portal has a plethora of research reports, datasets, case studies, educational institutes, courses, and articles about the ever-growing field of AI.

BOX 3: FutureSkills Prime (Govt. and Industry Linkage)

Objective

Continuous upskilling and reskilling of IT and ITeS professionals in 10 emerging areas such as, big data analytics, virtual reality, blockchain technology, artificial intelligence, 3-D printing / additive manufacturing, cybersecurity, Internet of Things, robotics process automation (RPA), social and mobile, and cloud computing primarily to enable the Indian industry to tap into market opportunities.[60]

Approach

A joint initiative of the Ministry of Electronics & Information Technology (MEITY), the nodal ministry for IT and ITES and the tech industry representative NASSCOM, called "FutureSkills Prime" was launched in 2019 with the aim of reskilling or upskilling close to 400,000 IT and ITeS professionals in India in the ten emerging tech areas. It aims to achieve high-impact skill enhancement of IT and related professionals, through an online learning portal offering self-paced high quality learning content and architecture critically relevant to the industry. Learners opting for paid courses are incentivised through cashback offerings after the successful completion of modules. With an objective of extending its reach in non-urban areas and remote locations, the programme offers blended-learning options through the network of training centres under the Centre for Development of Advanced Computing and the National Institute of Electronics and Information Technology[61]. FutureSkills Prime also offers trainings for government officials, targeting technical and scientific officers to make them familiar with the nuances of emerging technologies through industry-curated courses.

Anticipated outcomes

FutureSkills Prime is one of the lighthouse schemes under the government's "Trillion Dollar Digital Economy" initiative to transform India's digital landscape by 2024. Besides its B2C programme targeting 0.4 million individuals, the government also aims to train 1 million IT and ITES companies' staff through its B2B skilling where companies have a stake.

[60] Sourced from: https://pib.gov.in/PressReleasePage.aspx?PRID=1767604
[61] Sourced from: https://nielit.gov.in/delhi/content/about-fsprime

BOX 4: Open Network for Digital Commerce (GOVT-BUSINESS Linkage)

Objective

The "Open Network for Digital Commerce (ONDC)" was launched by the Department for Promotion of Industry and Internal Trade (DPIIT) in 2021 to connect all e-commerce players into one network for widening digital advantages to smaller retailers and local businesses, and to curb digital monopolies. By achieving democratisation and decentralisation of e-commerce businesses ONDC wants to accelerate the growth of online retail beyond its 5% share of the total retail market of US$ 1 trillion

Approach

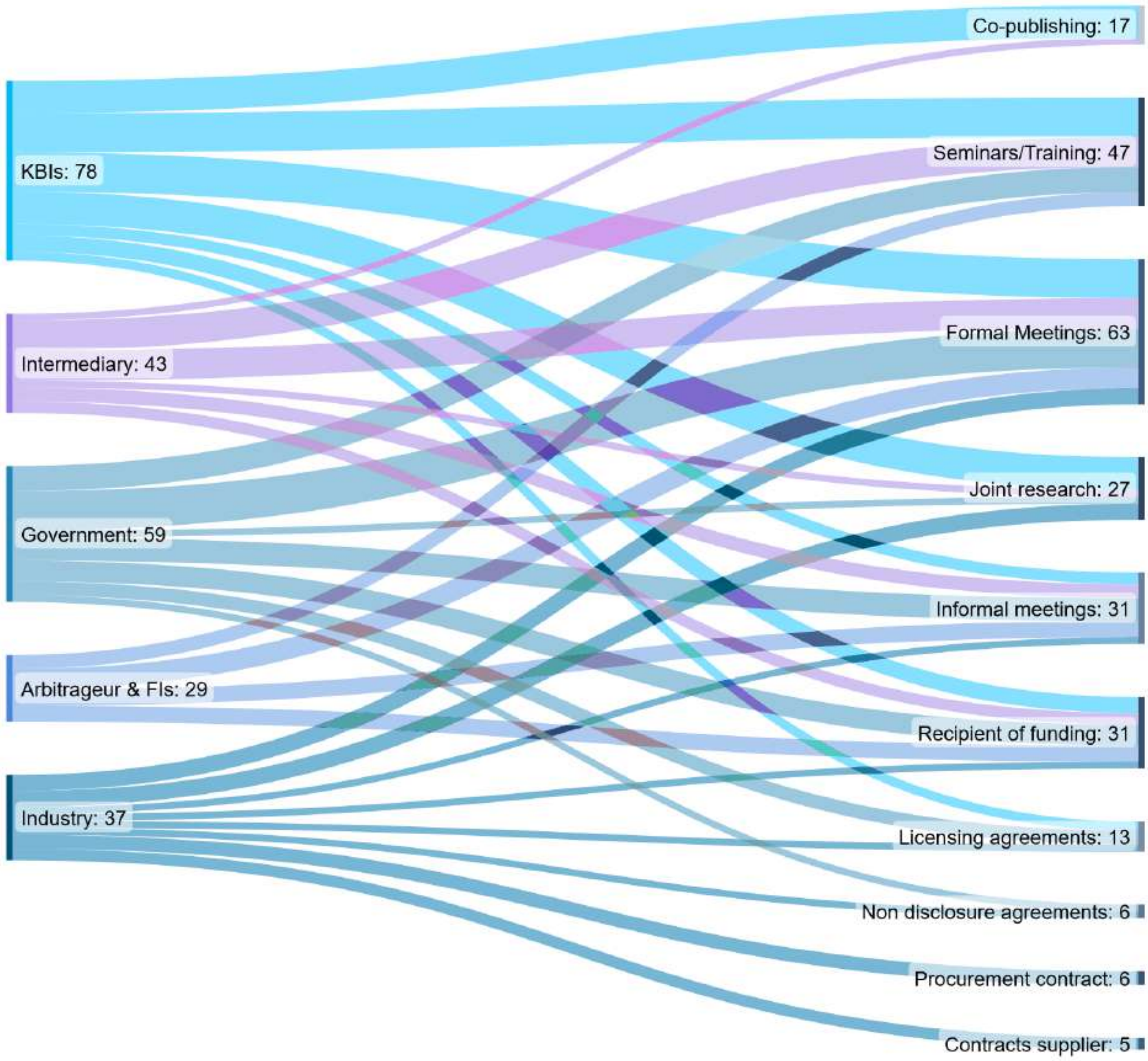
ONDC, implemented by the Quality Council of India (QCI), promotes open networks developed on open-source methodology and protocols to ensure inclusivity and access for smaller players to achieve digitisation and standardisation of value chains, thereby improving the efficiency of logistics and costs[62]. It is not a universal platform or platform of platforms, but a network that unifies siloed platforms and overcomes the challenges inherent in the platform model. It aims to create a shift from central platforms storing and exchanging value to a decentralised network of interconnected ecosystem actors orchestrating the flow of value. It enables autonomy of buyers and sellers through discoverability and trust, agnostic of a platform and across platforms. In turn, this allows larger freedom to consumers to potentially discover any seller, product, or service by using any ONDC-compatible application or platform.

Outcomes

ONDC is expected to follow the success trajectory of the Unified Payment Interface (UPI) Model for credit enablement, where over the last 5 years, the volume of transactions via UPI went from INR 2.38 lakh in 2016 to INR 10 lakh crore. Leveraging UPI services and demand aggregation, ONDC is positioned to positively impact supply chains. Thus retailers, suppliers and logistics providers are envisioned to work more efficiently and democratically[63]. In April 2022, the DPIIT launched the ONDC app to sensitise the buyers, sellers, seller apps, logistics providers and others in five cities - Delhi NCR, Bengaluru, Bhopal, Shillong, and Coimbatore. The first beta testing was held in October in Bangalore for grocery and food domains, with the participation of 3 buyer apps, 11 seller apps, 3 logistics providers across 16 pin codes64. Many more partners are in the process of joining the network.

[62] Sourced from: https://www.pib.gov.in/PressReleasePage.aspx?PRID=1732949
[63] Sourced from: https://www.business-standard.com/article/companies/ondc-and-upi-together-will-reorder-india-s-supply-chain-nandan-nilekani-122092001173_1.html
[64] Sourced from: Centre's Open Network for Digital Commerce opens on pilot basis in Bengaluru | Bengaluru - Hindustan Times

FIGURE 20: Government relationships



6.2.4 Intermediary

Figure 21 highlights intermediaries intra- and inter-linkages.

Intra-relationships

The main intra-linkages reported are formal and informal meetings along with seminars and training. This indicates high tacit knowledge transfer between intermediaries that, as was previously elucidated, is crucial for idea generation and sharing.

Clear platforms for structured communication include CII Associations' Council (ASCON), an important forum of the CII which brings together national level associations from across sectors on a common platform. Every year, an ASCON summit is organised and as part of this summit, a sectorial roundtable with industry members is conducted to discuss the key issues faced by the sector and to arrive at the recommendations to be made to the government. Areas of focus include investment, cost of doing business, ease of doing business, trade; technology & R&D, and job creation and skills.

The Indian STEPs & Business Incubators Association (ISBA)[65] is a common platform for networking and the facilitation of knowledge transfer between incubators across the country. The ISBA conducts a yearly conference which is its flagship networking event that brings together incubators with experts, investors, government and other stakeholders of the techno-entrepreneurship ecosystem. In recent years, the focus of these platforms has been topics such as startup incubation; Entrepreneurship 4.0; the future of Indian incubation; design change manage growth; innovation

[65] Sourced from: https://isba.in/

through incubation; the way forward for sustained inclusive growth; and creating an innovation economy through entrepreneurs and incubation.

Inter-relationships

With respect to inter-relationships the most prominent are those of the intra relationships, namely: seminars and training, formal and informal meetings, recipient of funding and joint research.

Formal meetings, seminars and trainings would underscore the function of industry associations in providing a collective voice for their members and conveying the same to the government. Actively building and maintaining relationships through discussions, meetings or workshops can lead to intermediaries contributing to the process and can increase the likelihood that experience will inform policy decisions. NASSCOM is the apex body for the US$ 227 billion IT BPM industry in India. The pillars of NASSCOM’s work are to:

- Reskill and upskill India’s workforce to ensure the talent is future ready in terms of new age skills and jobs.
- Strengthen India's innovation quotient and impact.
- Drive policy advocacy to advance trust, innovation and ease of doing business.
- Create new market access in India and across the globe.
- Champion equal opportunities and diversity.

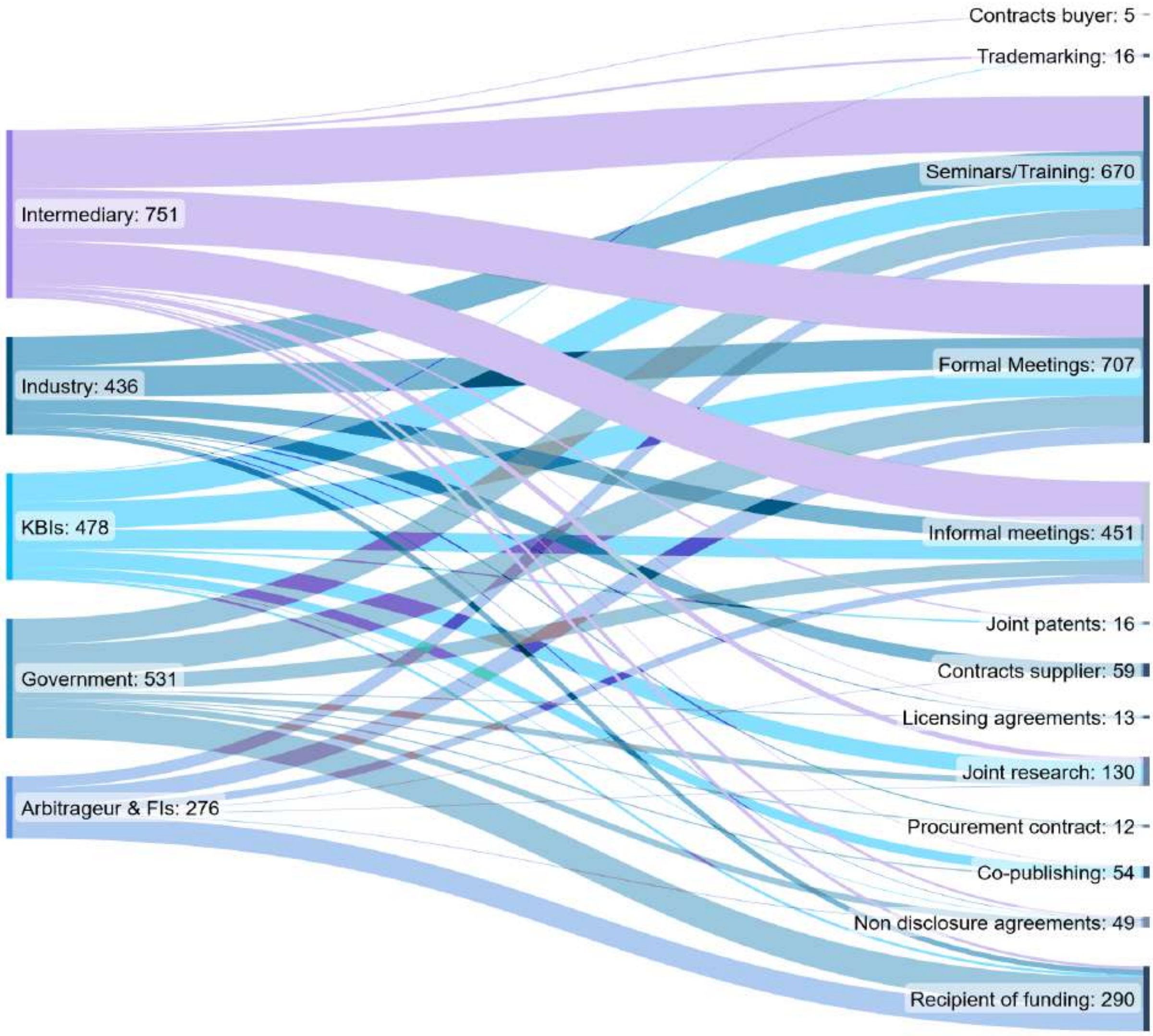
In sum, it is focused on building the architecture integral to the development of the IT BPM sector through policy advocacy and helps in setting-up the strategic direction for the sector.

Some of the leading platforms which inform the sector include the Annual Technology Conference, GCC Summit, and leadership forums with the objective to discuss various tenets of technologies and their applications in the ICT sector. The NASSCOM Technology and Innovation Conclave, with key themes including: the metaverse, FinTech, deep tech, health tech, Cloud and 5G, retail tech, diversity and inclusion and cybersecurity, is another such example.

With respect to intermediary interaction with knowledge-based institutions, a collaboration has been established by the Indian Institute of Information Technology (IIIT) Sri City, Chittor through an MoA with the Data Security Council of India, set-up by NASSCOM for conducting joint academic and research programmes in cybersecurity. The MoA is part of preparation to support a new B.Tech specialisation in cybersecurity launched by the IIIT Sri City.

In the case of incubators supporting the innovation process, the HDFC Bank signed an MoU with the Enterprise Incubation Centre (EIC) of premier B-school IIM Lucknow’s Noida campus. The MoU seeks to help startups with mentoring, training, product acceleration, and banking services.

FIGURE 21: Intermediary relationships



6.2.5 Arbitrageurs and Financial Institutions

Figure 22 highlights arbitrageur and financial institution intra- and inter-linkages.

Intra-relationships

The main intra-linkages reported are formal and informal meetings, seminars and training and as recipients of funding.

In order for arbitrageurs and financial institutions to effectively stay on track with the market and assess risk, information flow is crucial. Financial institutions are joining forces with startups to jump-start innovation, especially in payments. Banking, financial services and insurance (BFSI) companies are collaborating with FinTech companies rather than developing their own in-house solutions, taking advantage of proven technologies and business models while also often saving costs.

BFSI companies are looking at solving the core problems through partnerships. This is exemplified by the case of banks tying up with non-banking financial companies (NBFCs) under a co-lending model, where NBFCs can leverage a huge balance sheet while banks get access to a large customer base. Such partnerships are creating a symbiotic relationship that can propel the two diverse institutions forward as it is difficult to operate in a silo in an increasingly digital world. Consequently, the fourth ETBFSI CXO Conclave, organised by Economic Times, focuses on sharing knowledge and strengthening partnerships, fostering connections between financial institutions, and sharing best practices.

An example of funding flows between financial institutions is how the State Bank of India (SBI), has entered into a co-lending agreement with U GRO Capital (a technology focused small business lending platform) to offer strategic financing solutions to the unserved and underserved MSMEs of the country in line with the Reserve Bank of India guidelines.

Inter-relationships

With respect to inter-relationships, once again formal and informal channels of communication are prominent, followed by knowledge dissemination activities in the form of seminars and training, followed by those as recipients of funding.

As was previously highlighted formal communication contributes to the process of sharing information, exchanging and developing ideas, as well as expressing disagreement, and managing conflict (Shasitall, 2022) which are crucial to the innovation process. This can be seen to translate into novel services being offered in the engagement between industry and financial institutions. An example of this is FinTech companies offering behavioural intelligence support to banks for customising their products. Tata Consultancy Services (TCS) and the State Bank of India extended partnership builds on a two-decade long relationship between the two partners, that began with the implementation of the "TCS BaNCS™" core banking solution in 2001, the largest such transformational programme of that era. TCS will continue to maintain and enhance SBI's application estate around core banking, trade finance, financial reporting, and financial inclusion with new features and functionality. However, in addition it will leverage its deep contextual knowledge of SBI's business and technology landscape to help execute large transformation programmes. In the most recent engagement, TCS is helping build Bharat Craft - an omnichannel, online B2B e-commerce platform - which would serve as a marketplace for MSMEs, jointly driven by SBI and the Government of India. Prior to this, TCS collaborated with SBI to plan and execute the simultaneous merger of five associate banks and Bharatiya Mahila Bank. The colossal undertaking involved integrating over 200 business processes, over 43 IT applications, 17,500 products, and over 50 billion database records, impacting over 50,000 tellers across 7,000 branches[66].

Formal and informal communication between arbitrageurs and financial institutions and government generally orient around investment policies. The needs of startups are unique, and customised financial offerings and services would make them more accessible. Beyond VC (venture capital) funding, credit facility from banks plays a significant complementary role in ensuring capital adequacy for startups. Cognisant of this, the State Bank of India (SBI) and Karnataka Digital Economy Mission (KDEM) in a joint initiative has formed the "SBI Start-Up Branch" which is dedicated to funding and supporting early-stage entrepreneurs in setting-up new companies until their listing on the stock exchanges. The exclusive branch for startups will provide services such as loans, deposits, transaction banking, outward and inward remittances, payments, cash management, forex, insurance, custodial services, capital market and legal advisory, structuring, demat and trading. This is a reflection of the foresight being undertaken as Karnataka was identified as the best performer in the central government's State Startup Ranking-2021 for developing a strong startup ecosystem through holistic and inclusive policies for sector-focused incentives, regulatory sandboxes and supporting innovation in disruptive sectors.

Engagement with knowledge-based institutions can be seen through the fostering of knowledge transfer. An example is the National Institute of Bank Management (NIBM), Pune offering training programmes to bank executives and publishing journals like "Prajnan" and "Vinimaya". In addition, institutions of national importance like the IIT Kharagpur and IIT Bombay have entered into MoUs with SBI for promoting FinTech innovation[67]. The focus of the programme includes ideation, incubation, experimentation and commercialisation of new technology-driven products and services for the banking sector.

Knowledge dissemination in collaboration with intermediaries is evidenced through fora and seminars such as the Banking Technology Conference, Expo & Awards, 2022 organised by the Indian Bank's Association[68]. The event is focused on addressing current issues related to technology, banking, and finance. Participants range from both national and international CEOs, to regulators, practitioners, and representatives of the knowledgebase.

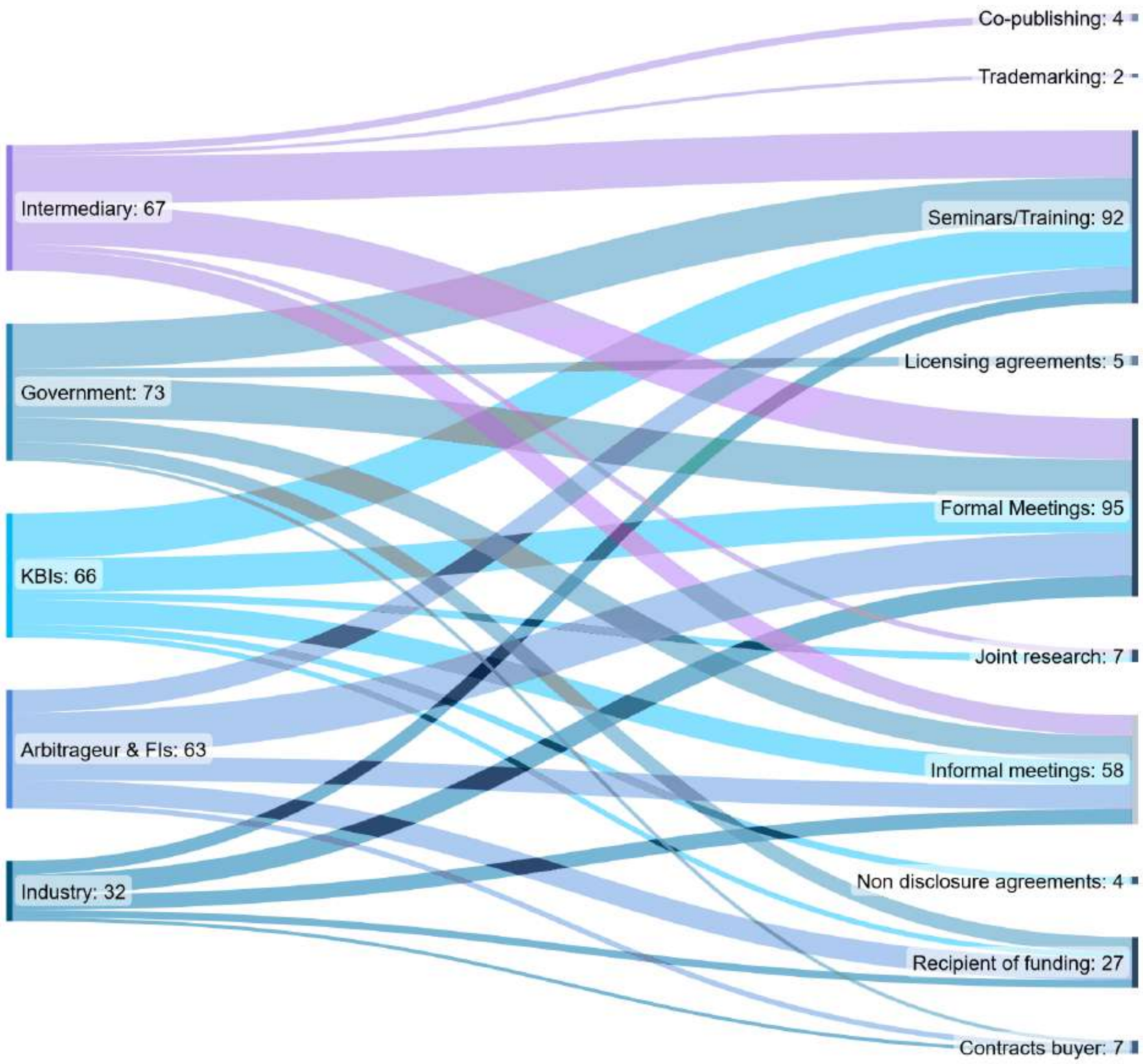
It is clear that the landscape of banking has changed, and digital banking has emerged as the preferred banking service delivery channel. The Reserve Bank of India (RBI) has been taking measures to improve the availability of digital infrastructure for banking services. To this end, the concept of Digital Banking Units (DBUs) is being introduced by the Reserve Bank and guidelines have been prepared for setting them up by a working group including representatives from banks and the Indian Banks' Association (IBA)[69].

The Financial Inclusion Fund18 (FIF) and Financial Inclusion Technology Fund (FITF) were constituted in FY 2007-08 for

[66] Sourced from: https://www.tcs.com/sbi-deepens-partnership-with-tcs-drive-innovation-enhance-customer-experience
[67] Sourced from: https://economictimes.indiatimes.com/industry/banking/finance/banking/sbi-iit-kharagpur-to-collaborate-on-fintech-innovation/articleshow/54660990.cms?from=mdr
[68] Sourced from: https://www.iba.org.in/publications/banking-technology-conference-expo-andamp-awards-2022_1382.html
[69] Sourced from: https://www.rbi.org.in/scripts/NotificationUser.aspx?Id=12285&Mode=0

a period of five years with a corpus of INR 500 crore each to be contributed by the Government of India (GoI), RBI and the NABARD in the ratio of 40:40:20. Keeping in view the various developments over the years, the GoI has merged the FIF and FITF to form a single Financial Inclusion Fund. The objectives of the FIF are to support developmental and promotional activities including: creating an FI infrastructure across the country, capacity building of stakeholders; awareness creation to address demand-side issues; enhancing investment in green ICT solutions; research and the transfer of technology; and increased technological absorption capacity of financial service providers/users with a view to securing greater financial inclusion. The fund shall not be utilised for normal business/banking activities.

FIGURE 22: Arbitrageur and financial institution relationships



In the relationships presented above, there are some interactions which are robust, however what emerges is the need to bolster certain truncated relationships in order to facilitate knowledge and resource flows within and between the actors and hence foster innovation. According to the literature, the scope and intensity of these interactions between the actors are reflected in varying institutional arrangements, referred to as Triple Helix Type I, II, and III (TH-Type I, II and III) (Etzkowitz and Leydesdorff, 2000; Etzkowitz, 2003b, 2008; Ranga and Etzkowitz, 2013). In the specific case of the ICT sector, we observe the TH-Type III arrangement, where the three actors assume each other's roles in the institutional spheres as well as the performance of their traditional functions. With the emergence of TH-Type III, a complex network of organizational ties has developed, both formal and informal, among the overlapping spheres of operations. The transformation of universities is of particular relevance as after having incorporated research as an additional mission beyond teaching, universities recognise their role in the pursuit of economic and social development (Etzkowitz and Leydesdorff, 2000; Webster, 2000; Ranga and Etzkowitz, 2013; Etzkowitz, 2008, 2017). Hence, universities take on entrepreneurial tasks such as marketing knowledge, increased technology transfers and the creation of spin-offs and startups as a result of both internal and external influences (Etzkowitz, 2017; Etzkowitz and Leydesdorff, 2000; Etzkowitz et al., 2000). These entrepreneurial activities are assumed with regional and national objectives in mind, as well as financial improvements to the university and the faculty (Etzkowitz, et al., 2000). The inter- and intra-interactions that need attention are:

- Fostering joint research between industry players, similarly for government and knowledge-based institutions, as well as government and industry, particularly in strategic areas such as quantum computing;
- Promoting secondments between knowledge-based institutions and the ICT industry as programmes benefit individuals and companies by developing new skills, boosting engagement, increasing retention and can also resolve the specific problems and needs of the ICT sector;
- Better connectivity between the knowledgebase and intermediaries, in particular industry associations in terms of technical knowledge dissemination; and
- Closer linkages between the knowledgebase and arbitrageurs to facilitate the process of ideation to market.

6.3 Barriers to Innovations

This section sets out to analyse the results of the IICTSSI Survey. It uses a multivariate analysis approach which provides a strong empirical foundation. The focus of this chapter is the elucidation of the barriers that exist within the ICT system of innovation. It is crucial to understand which barriers to innovation are significant for the ICT sector in order to critically understand where resources need to be applied to bolster the system of innovation and boost innovation for the sector. To this end, factor analysis is used to indicate the underlying factors that significantly influence barriers to innovation, enabling evidence-based policy design to be targeted specifically and accurately to remove the highest barriers to innovation in prioritised sequencing. Factor analysis condenses observed variables into factors in a pattern matrix (clusters of inter-correlated variables) with 'mutual interdependence' (Gaur, 1997). The factors represent the underlying structure that is responsible for the variation of variables in the data and thus the population (Kim Jae-On and Mueller 1978). The next section aims to articulate this both from the system perspective, as well as from the level of each individual actor.

Description of Table Structure

The column 'Factor Number' indicates the descending rank order (by importance) of the factor, which influences the sets of barriers to innovation variables. The column 'Factor Name' provides a description for the grouped variables influenced by the factor and enables meaningful policy discussion of the barriers to innovation. The factor names are assigned based on the factor loading of the variables taking the higher loading variables into consideration as well as the judicious use of empirical evidence and theory in the literature of SSI. The naming of factors therefore reflects the variables that are most influenced by the underlying factor, and hence there are commonalities and differences regarding actor responses. Furthermore, the column 'Factor Loading' indicates the correlation between factors and variables, i.e., the extent to which the factor influences the variable. The column 'Cronbach's Alpha' indicates the internal consistency and reliability of the factor, and hence the cohesion of variables as a group. The dominant heuristic, or commonly accepted rule of thumb for describing internal consistency and reliability using Cronbach's Alpha, is indicated in Table 12 (George and Mallery, 2003; Kline, 1999; Cortina, 1993).

For the purpose of policy analysis, factors influencing groups of variables with Cronbach's Alpha below 0.7 are deemed inconsistent and unreliable and are rejected for policy purposes. The factors enable economy-wide policy prescriptions, as well as actor (sector) specific policy prescriptions to be carefully and accurately designed.

The column 'Total Variance Explained' (TVE) indicates the amount of variance (variation) of the groups of variables in the data sample and population, which is accounted for by the factor. It is an indication of the extent or power of the influence of the factor. The column 'Kaiser-Meyer-Olkin' (KMO) is a measure of sampling adequacy. It indicates the robustness of the sample in terms of the distinct and reliable factors extracted (Kim Jae-On and Mueller, 1978). The Bartlett's Test of Sphericity (BTS) indicates the significant confidence level regarding the coherence of factors, reproducibility and generalisability of the results (Kaiser, 1974; Dziuban and Shirkey, 1974, p.359; Kim and Mueller 1978, p.54; Rummel, 1970) (see Table 13). For the individual actors, barriers to innovation are represented as a frequency analysis.

TABLE 12: Internal consistency of factor

Cronbach's Alpha	Internal Consistency/ Reliability
a ≥ 0.9	Excellent
0.9 > a ≥ 0.8	Good
0.8 > a ≥ 0.7	Acceptable
0.7 > a ≥ 0.6	Questionable
0.6 > a ≥ 0.5	Poor
a < 0.5	Unacceptable

TABLE 13: Kaiser-Meyer-Olkin (KMO)

Internal consistency of factor	
KMO = 1	Perfect
KMO > 0.9	Marvellous
0.9 > KMO > 0.8	Meritorious
0.8 > KMO > 0.7	Middling
0.7 > KMO > 0.6	Mediocre
0.6 > KMO > 0.5	Miserable
KMO < 0.5	Unacceptable

Source: Kim Jae-On and Mueller, 1978

From the analysis of all actors (see Table 14) four factors emerge which account for 42.75% of the total variance explained (TVE), namely, '**Industry 4.0**', '**Policy Function**', '**ICT Knowledge and Stocks**' '**Human Capital Silos**' and '**Finance**'.

Factor 1- '**Industry 4.0**' is the most significant factor barrier to innovation and accounts for 23.801% of the TVE within the sample, hence the population. When examining the factor loading, in order to understand the relationship of each variable to Factor 1, the internal consistency value for 'Lack of understanding of I4.0 technologies', 'Lack of access to I4.0 technologies', 'Cost of I4.0 technologies' and 'Lack of infrastructure for I4.0' is deemed to be 'Good' (Tabachnick and Fidell, 2007).

The 4IR consists of a set of complexes, interrelated and advanced digital production (ADP) technologies that has changed the face of global manufacturing. The key technology pillars of 4IR include Internet of Things (IoT), big data, artificial intelligence, robotics, additive manufacturing, cloud computing, augmented reality, virtual reality, cyber-physical systems, system integration and simulation. The complexity of 4IR technologies demands high interdependency of competences and technological complementarity (Dalenogare et al., 2018; Reischauer, 2018; Rübmann et al., 2015).

Implementation of 4IR technologies at a broader organizational level is required for a measurable impact of digital transformation. Transforming factories from being manual and labour-intensive to being automated and highly digitised requires enhanced capabilities, not limited to investment in technologies. Firms require a vast set of capabilities to digitally transform their entire operating model using 4IR technologies (Boer et. al, 2021). Such capabilities are hard to be found in a single technology provider, especially in the case of small and micro enterprises (SMEs) (APO, 2019).

Manufacturers across sectors have made in-house investments under their control into basic enterprise systems such as ERP, CRM and PLM. There is a basic awareness of what I4.0 is and the underlying technologies. However, the challenge is in mapping the concepts into business opportunities and challenges,and in coming up with use cases (combinations of technologies) as comprehensive solutions.

Therefore, the first step towards 4IR implementation is a clear understanding of the application of I4.0 technologies. There still exists a lack of understanding of the value, goals and needs of 4IR technology among many firms (Bai et al., 2020). Robust evaluation mechanisms and decision support tools can help manufacturing firms understand the impact of 4IR technologies and effectively implement them. A clear understanding of 4IR technologies, their benefits and impact can help firms develop an organization-wide 4IR strategy and set implementation targets. Educating the workforce on 4IR technologies and upskilling them is key to its effective implementation. A well-functioning innovation ecosystem can allow collaborations between system actors for knowledge sharing and awareness building. It will enable firms to integrate resources and co-create 4IR solutions (Grant Thornton & CII, 2017).

Areas beyond the control of firms such as infrastructure for telecom for 5G for example are lacking global levels of adoption, constraining their adoption and preventing them from realising the benefits from adopting them (e,g., low latency, high bandwidth telecom using 5G for real-time decision-making). The lack of understanding of the cost of I4.0 starts from the information asymmetry between traditional manufacturers and technology service providers, as these technologies are emerging areas. On top of these challenges, these technologies follow Moore's Law[70] and improve dramatically in terms of their capabilities, physical size, cost and reliability. Manufacturers should be agile to go along with this pace of change.

Factor 2 – '**Policy Function**' is a key foundation to an effective system of innovation (Reiljan and Paltser, 2015), and accounts for 9.65% of the TVE with 'Lack of legal framework', 'Restrictive public/ govt regulations', 'Lack of clear national innovation strategy', and 'Lack of higher resolution regulations' loading on it. The association between the variables in Cronbach's Alpha is 'Acceptable'.

It is generally recognised that the public sector has an important role in promoting innovation – its task is to support the development, diffusion and implementation of innovations (Edquist 2006, p.182) through the creation of effective incentives and disincentives. Public sector intervention in the economy is usually justified by the need to overcome market and system failures. With the support from national regulations (laws, standards and norms) and public sector institutions, the task of policy is to integrate both formal and informal institutions (social, political, economic, educational, scientific, etc.) of the society in order to create and develop a conducive environment which guides economic agents to innovate and increase their competitive performance. The government sector directly guides the innovation processes through various political support activities (public procurement, tax breaks, subsidies, etc.). The activities and effectiveness of economic units in their innovation processes is largely dependent on the smooth functioning of the innovation system, including the effectiveness and coordination of innovation policy measures (Reiljan and Paltser, 2015).

The convergence of various technologies like the ubiquity of the Internet, emergence of an app economy, and pervasiveness of social media have caused a paradigm shift in the Indian ICT industry. This poses several policy and regulatory challenges in the areas of industry structure, market power of firms, pricing of products and services, interconnection of networks, radio spectrum management, intellectual property rights, data privacy and security. (Carnige, 2020). With respect to consumer and producer welfare, India's adoption of consumer welfare standards is not very dynamic, which has an impact on competition and innovation. MSMEs and startups are unable to compete with large multinationals which leads to bankruptcy.

There is a need to set a clear boundary between the Indian regulatory authorities and their executive powers. To elucidate, under the data protection bill, in most cases, this boundary is clearly defined, however, the capabilities of the proposed Data Protection Authority (DPA) are still unclear. In order to prevent the DPA from abusing it powers, a recommendation would be to subject them to regular checks through mandating periodic reports to parliament (Carnige, 2020).

Specific examples from the Indian ICT sector of the bottlenecks that emerge include the lack of patenting norms for software in India as compared to countries such as the UK, Europe and Japan, but only under copyright. However, copyright law fails to safeguard the technical aspects or functionalities of the software program. A broader form of protection is guaranteed by the patent Law. However, the patentability of software programs or Computer Related Inventions (CRI) has been a subject of major confusion in various jurisdictions.

Factor 3- '**ICT Knowledge and Stocks**' accounts for 7.23% of the TVE in the sample hence the population. The variables that load on the factor are: 'Rate of access to ICT', 'ICT capacity', 'Lack of technology (technology gap)' and 'Lack of information (knowledge gap)' and are deemed to be 'Acceptable' in terms of the Cronbach's Alpha. Increased ICT adoption reduces information asymmetry (Mushtaq et al., 2022) and information flows are vital for the innovation process (Allen 1977; Katz and Tushman 1981; Tushman and Scanlan 1981; De Meyer 1985; Macdonald and Williams 1993; Assimakopoulos and Yan 2006; Allen, James et al., 2007; Doak and Assimakopoulos 2007).

With digital technologies getting increasingly embedded in products and across their lifecycle from conceptualisation, design, manufacture, operation, service and end-of-life, traditional manufacturers in India face the issue of information asymmetry when compared to digitally native newcomers or technology partners with whom they need to collaborate and negotiate. E-Market places are one way

[70] Moore's Law states that processor speeds or overall processing power for computers will double about every 18 months. Sourced from: https://hasler.ece.gatech.edu/Published_papers/Technology_overview/gordon_moore_1965_article.pdf

in which information technology removes some of the asymmetry, at least around pricing. Marketplaces create an ideal platform for buyers and sellers to interact, while competition lets price discovery happen. Traditional manufacturers who are not familiar with digital technologies can leverage the transparency inherent in marketplaces to rate technologies and their providers, arrive at a fair price and not get cheated. However, to make use of marketplaces, the players should be aware of them and the inherent processes to buy or sell on them. Good quality connectivity is required to access the marketplace itself. Seamless information flow is important across the ecosystem, reflecting market dynamics.

Factor 4- '**Human Capital Silos**' underscores the question of how firms can effectively identify, mobilise and deploy human capital, which is a crucial issue (Lippman and Rumelt, 2003; Sirmon et al., 2007; Wang et al., 2011) particularly with the paradigm shift caused by digital transformation and the 4IR.

The TVE, by the factor is 5.70%, and the variables loading on the factor are 'Lack of technically trained manpower', 'Quality of technically trained manpower' and 'Lack of willingness to share knowledge' with an 'Acceptable' Cronbach's Alpha value for internal consistency.

Human capital is a collective resource that emerges from the knowledge, skills, and abilities of employees (Wang et al., 2011). For example, training helps employees maintain state-of-the-art skills and enables them to use the skills in innovation (Lau and Ngo, 2004). With the advent of the 4IR, a number of changes in human skills and tasks is being observed with a shift in direction and the need for learning and reskilling (da Silva, 2018). Digital transformation and the 4IR have led to a wave of change from the economy to society. Within the industrial context this change has led to the expansion of cyber-physical systems (CPS). With regard to human interaction, these systems use a separate concept—the cyber-human system (CHS). It is expected that the development of the CPS and CHS will deeply modify the production sector. Consequently, there is a consensus that human labour requirements will also include a requirement for different skills. 4IR will lead to a significant decrease in low-skill activities and an increase in activities requiring specialised knowledge including planning, control and information technology (IT) tasks (Bonekamp and Sure, 2015). This will lead to a rise in the complexity of many professional profiles and will necessitate a more intensive and time-consuming process of learning, training and continuous self-improvement. (Ligarski et al., 2021). In general, it is evident that actors within the sector are more competitive than collaborative with a reluctance to exchange knowledge and information.

Historically, India became a global player due to markets opening up and the cheap and vast manpower having knowledge of English. Between 1991 and 2000, Indian companies grew at a mind-boggling rate of 200- 500%, attracting lucrative projects from companies all over the world, especially the US (Khan, 2017). However, this is no longer the case given the global economic downturn. The challenge being faced by Indian ICT companies is that most global corporations prefer to keep the most lucrative projects for their employees and the remaining for Indian companies; the lack of an aptly skilled workforce being one of the major reasons (Kumari and Nirban, 2018).

In real terms human capital has always followed a siloed approach, following specific departments and functions, starting from educational institutions to corporates. But emerging areas like I4.0 on the technology-side, and products have become multi-disciplinary in nature. This siloed approach becomes a barrier for adopting emerging concepts. For organizations to be successful in making these products efficiently using I4.0, human capital that have a holistic perspective about application of these technologies is important. Knowledge of operating software from basic spread sheets to programming of machine tools or robots will become a basic necessity across industries and functions. Businesses need to start restructuring themselves around micro-enterprises with all necessary skill sets, and not the traditional functional approach.

Factor 5- '**Finance**' has the variables 'Lack of finance', 'Innovations costs (too high)' and 'Excessive perceived economic risk' loading on it with a TVE of 5.312% and a Cronbach'. Alpha value which is deemed as 'Questionable'. SMEs in India face a multifold and vicious circle of financial challenges in pursuing innovation. Firstly, the cost of innovation itself is high; secondly, SMEs lack the financial resources to implement innovation; and lastly, access to finance from external financial institutions seems to be limited, creating further bottlenecks. Therefore, there is an urgent need to address this challenge by bringing down the cost of innovation and increasing the availability of innovation capital through banks and other support mechanisms (ADB, 2016).

Factors 2, 3, 4 and 5 are significant but collectively only account for 27.90% of the TVE. Factor 1 ranks as the most important factor as it contributes close to 23.80% of the TVE and should be the main focus of system-oriented policies. Once again this expounds the importance of Industry 4.0 technologies as a driver for innovation, particularly for the ICT manufacturing sector.

The overall implications for policy emerging from the analysis of barriers to innovation is that resources should be used on two levels. Firstly, at the level of the system through more overarching interventions, and secondly at the individual actor level in order to address their specific needs. Each of these will be articulated in the "Recommendations" chapter. A structured dialogue between stakeholders is required to orient which policies can be most effectively used to address barriers and challenges. Policies and their targets should not be unattainable or 'out of reach' but issues need to be addressed from a realistic perspective.

TABLE 14: System-wide barriers to innovation

Barriers to innovation faced by all actors in the ICT sector (N = 304)									
Factor Number	Name of Factor	Variables	Factor loading	Cronbach's Alpha	Total Variance Explained (TVE)	KMO	Bartlett's Test of Sphericity		
							Chi squared	Df	Sig.
1	Industry 4.0	Lack of understanding of I4.0 technologies	0.838	0.852	23.80%	0.8	2955.022	351	0
		Lack of access to I4.0 technologies	0.815						
		Cost of I4.0 Technologies	0.756						
		Lack of infrastructure for I4.0	0.731						
2	Policy and Function	Lack of legal framework	0.8	0.777	9.65%				
		Restrictive public / governmental regulations	0.76						
		Lack of clear national innovation strategy	0.742						
		Lack of higher resolution regulations	0.661						
3	ICT Knowledge and Stocks	Rate of access to ICT	0.822	0.785	7.23%				
		ICT Capacity	0.818						
		Lack of Technology (Technology Gap)	0.567						
		Lack of information (Knowledge Gap)	0.539						
4	Human Capital silos	Lack of technically trained manpower	0.866	0.754	5.70%				
		Quality of technically trained manpower	0.82						
		Lack of willingness to share knowledge	0.562						
5	Finance	Lack of Finance	0.701	0.625	5.32%				
		Innovations Costs (Too High)	0.679						
		Excessive Perceived Economic Risk	0.588						
Cumulative Total Variance Explained						51.704%			

The determinant of the R matrix should be greater than 0.00001; if it is less than this value, look through the correlation matrix for variables that correlate very highly (R > .8) and consider eliminating one of the variables (or more depending on the extent of the problem) before proceeding[71]

6.4 Success of Policy Instruments

Having analysed the barriers to innovation, both at the actor and system level, it is important to ascertain how actors perceive various policies, and consequently, an understanding of whether or not they are effectively calibrated and configured to reach their intended target's needs. To begin with, it is important to understand what public policy instruments comprise "a set of techniques by which governmental authorities wield their power in

[71] Sourced from: http://users.sussex.ac.uk/~andyf/factor.pdf

attempting to ensure, support and effect (or prevent) social change" (Borras and Edquist, 2013., pg.1515). Unsurprisingly, the objectives of innovation policy have to do with the different national traditions and forms of state-market-society relations, not to mention the orientation of governmental ideology.

Generally speaking there are three main categories of policy instruments: i) Regulatory instruments[72]; ii) Economic and financial instruments (also referred to as market-based instruments)[73]; and iii) Soft instruments (also behavioural instruments)[74]; and iii) Soft instruments.[75] Phrased differently, these can be considered as "sticks", "carrots" and "sermons". In this vein, the respective perceived success or failure of national policies is reviewed grouping them as per the aforementioned classifications.

An alternative way to classify innovation policy is in terms of supply-side measures and demand-side measures (see Figure 23). Supply-side policies are seen to create a supply push to innovate (Voß and Simons, 2014); whereas "demand-side innovation policies are defined as all public measures to induce innovations and/or speed up diffusion of innovations through increasing the demand for innovations, defining new functional requirements for products and services or better articulating demand" (Edler and Georghiou, 2007., pg. 953). Supply-side measures can be further split into the grouping of finance (equity support, fiscal measures, support for public research, support for training and mobility, and grants for industrial R&D) and services (information and brokerage support and networking measures).

Demand-side policies can be presented in four main groupings: systemic policies, regulation, public procurement, and stimulation of private demand (Edler and Georghiou, 2007).

Using this classification to order policy instruments of the Indian manufacturing sector, the following groupings emerge: i) Supply-side finance policies – research grants, subsidised loans, government-backed venture capital, donor funds; ii) Supply-side services – ICT access and focused skills development initiatives; iii) Demand-side measures – tax breaks, spatial policies, government procurement, standards setting, regulation and labour mobility (laws and incentives). The system as a whole, as well as the views of each of the individual actors will be reviewed to understand how successful policy is through the aforementioned lens.

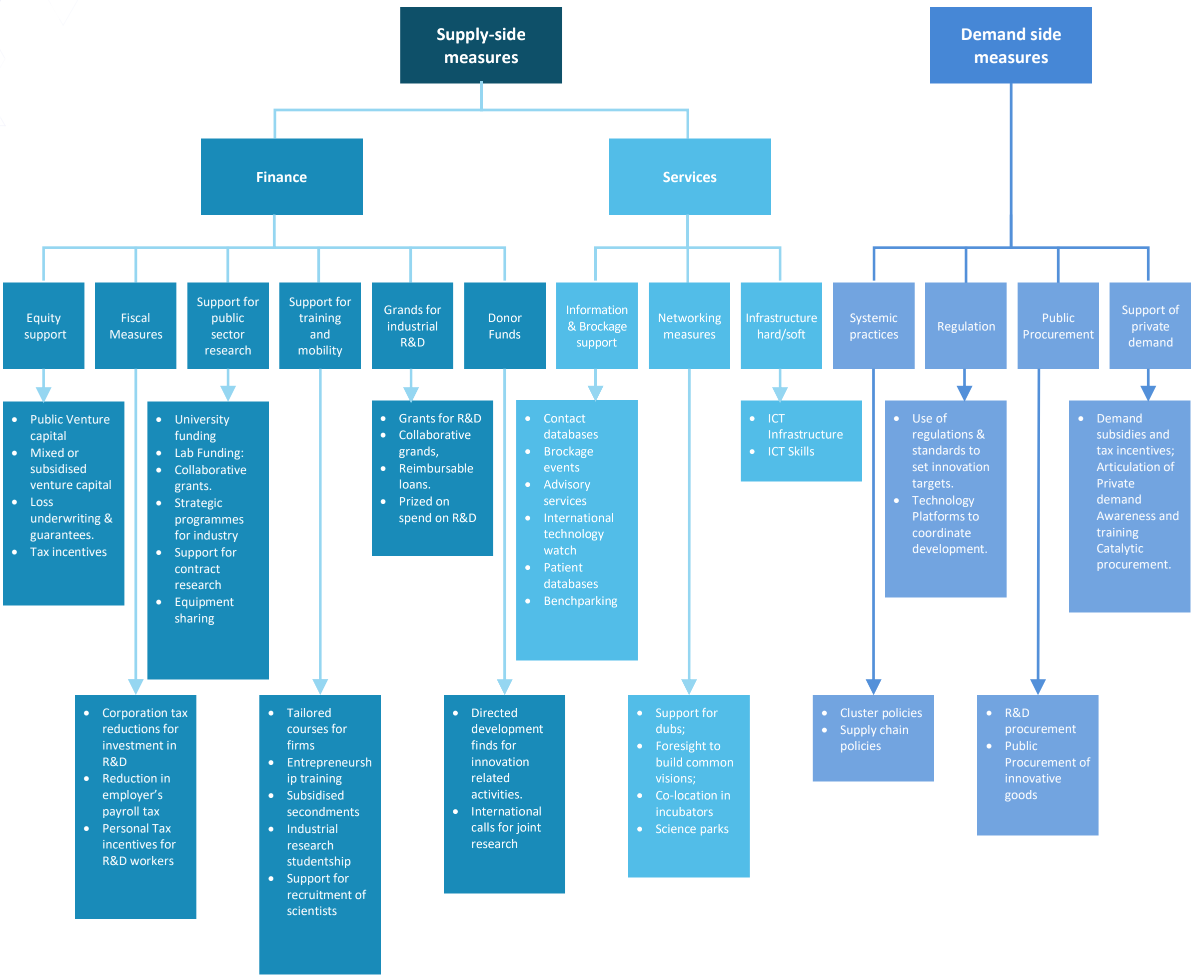
[72] "The first type, regulatory instruments, use legal tools for the regulation of social and market interactions. The logic behind this type of instrument is the willingness of the government to define the frameworks of the interactions taking place in society and in the economy. Naturally there are many different types, but common to them all is that these regulatory instruments (laws, rules, directives, etc.) are obligatory in nature, meaning that actors are obliged to act within some clearly defined boundaries of what is allowed and what is not allowed. Obligatory measures are typically backed by threats of sanctions in cases of non-compliance. These sanctions can be very different in nature (fines and other economic sanctions, or temporary withdrawal of rights), depending on the content of the regulation and the definition of legal responsibility. Some authors believe that sanctioning is the most crucial property of regulatory instruments (focusing on the imposition and hierarchical side of regulation). Others see the normative authority of governments as the most important feature of these instruments (hence focusing on the normative-positive side of obligatory regulation). From the point of view of innovation policy, regulatory instruments are often used for the definition of market conditions for innovative products and processes" Borras and Edquist, 2013., pg.1516.

[73] "Economic and financial instruments provide specific pecuniary incentives (or disincentives) and support specific social and economic activities. Generally speaking, they can involve economic means in cash or kind, and they can be based on positive incentives (encouraging, promoting, certain activities) or on disincentives (discouraging, restraining, certain activities)" Borras and Edquist, 2013., pg.1516.

[74] "Economic and financial instruments provide specific pecuniary incentives (or disincentives) and support specific social and economic activities. Generally speaking, they can involve economic means in cash or kind, and they can be based on positive incentives (encouraging, promoting, certain activities) or on disincentives (discouraging, restraining, certain activities)" Borras and Edquist, 2013., pg.1516.

[75] "Soft instruments are characterised by being voluntary and non-coercive. With soft instruments, those who are 'governed' are not subjected to obligatory measures, sanctions or direct incentives or disincentives by the government or its public agencies. Instead, the soft instruments provide recommendations, make normative appeals or offer voluntary or contractual agreements. Examples of these instruments are campaigns, codes of conduct, recommendations, voluntary agreements and contractual relations, and public and private partnerships. These Instruments are very diverse, but generally based on persuasion, on the mutual exchange of information among actors, and on less hierarchical forms of cooperation between the public and the private actors." Borras and Edquist, 2013., pg.1516.

FIGURE 23: Policy taxonomy

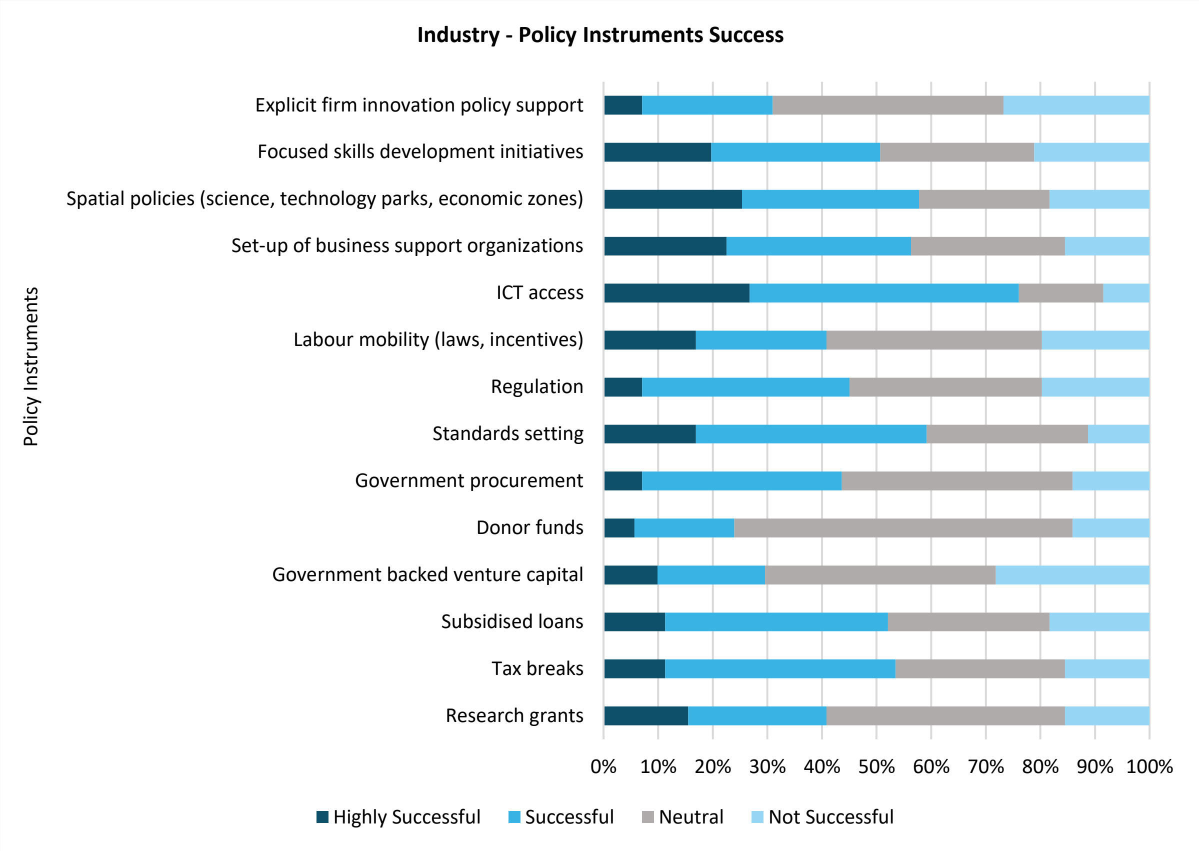


6.4.1 Industry

From the perspective of industry respondents (see Figure 24 below), the supply-side service, namely 'ICT access', emerges as the most successful policy instrument as reported by 76% of survey respondents in total (27% reporting it as 'Highly Successful' and 49% reporting it as 'Successful'). This is followed by the demand-side measures of 'Standards setting' and 'Spatial policies' which have been reported as successful by 59% and 58% of respondents respectively. The importance of ICT access is recognised by the "National Policy on Information Technology 2012" as it highlights the need "to enable long-term partnership with industry for: i. use of ICT in cutting-edge technology for improved efficiency and productivity; ii. Driving development of new ICT technologies through strategic sectors; and iii. Facilitating growth of IT SMEs and use of IT across all SMEs" (MEITY, 2012:7). Contrary to this, it is important to highlight that in accordance with the Global Innovation Index (GII), while India has been ranked 46th out of 132 economies, the country's ICT access ranking declined from 108 in 2012 to 111 in 2021.

Standards are known to be a driver for innovation and catalyse firms to change their behavioural patterns and enable them to be more technologically adaptive, leading to overall increased productivity and competitiveness. The Bureau of Indian Standards (BIS) is the national standards body of India that offers certification services to the industry and serves as an effective link between state governments, industries, technical institutions, and consumer organizations of the respective region.

FIGURE 24: Success of policy instruments – Industry



The Telecommunication Engineering Center (TEC) is another important government standards development organization (SDO) functioning in the telecommunications domain. It was formed under the Department of Telecommunications (DoT) with a mandate to "formulate technical specifications in the form of the standards of various telecommunication technologies for telecom equipment, networks, systems and services to be deployed in the Indian telecom network, in harmony with international standards after wide stakeholder consultations." As a testing and certification body, it proactively interacts with stakeholders and industry associations. In addition, there has been an increased effort in setting-up public-private partnership organizations for formulating standards focused on ICT standardisation (Ramakrishna et al., 2012). There are also global consortiums trying to bring about interoperability standards, which is a challenge in the telecom sector specifically for the IoT.

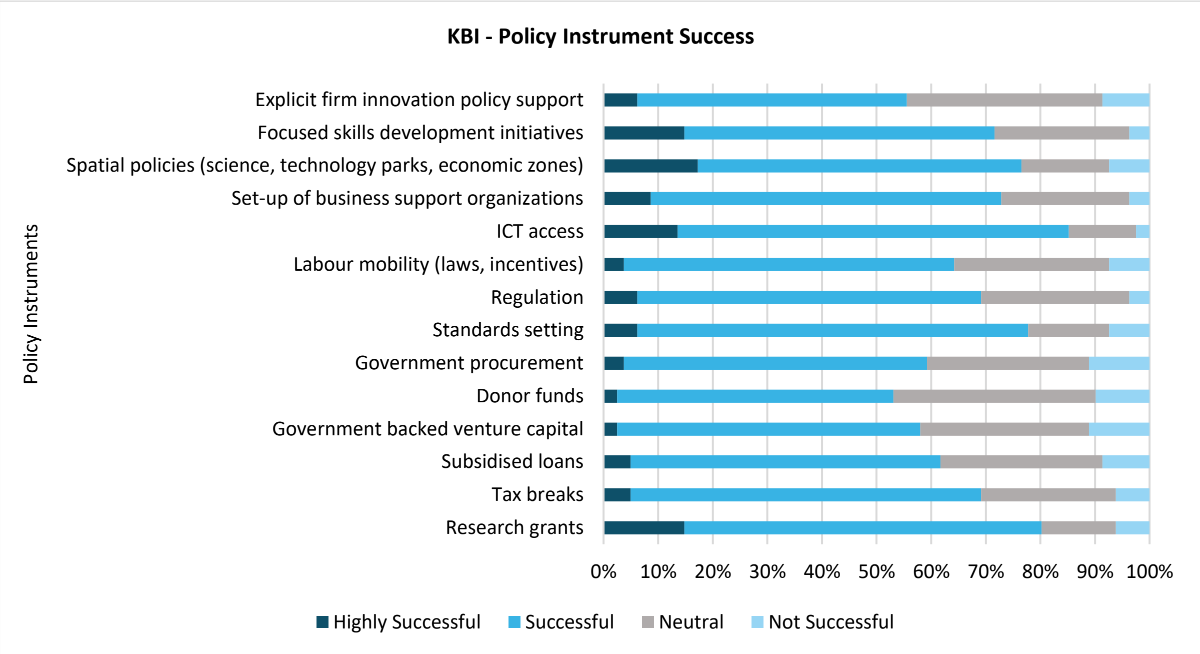
Proximity is an important dimension of the effectiveness and efficiency of a system of innovation in terms of connectedness and linkages which facilitate the flow of knowledge and resources between the actors. This is achieved through spatial policy instruments such as special economic zones (SEZs), cluster development and aggregation, as well as industrial and technology parks. For example, the Ministry of Electronics and Information Technology (MEITY) set-up the Software Technology Parks of India (STPI) in 1991 with the objective of promoting software exports from the country. STPI acts as a 'single-window' in providing services to the software exporters. The development of software technology parks, and patterns of spatial agglomeration in the IT sector and public-private partnerships have led to the emergence of a strong ICT industry in india (Mathur, 2006).

'Government-backed venture capital' is the most unsuccessful policy instrument reported by 28% of respondents, closely followed by the 'Explicit firm innovation policy support' reported by 27% of industry respondents. With respect to 'Government- backed venture capital', government policies understand that there is a need for "avenues for entrepreneurship development through incubators and accelerators to support scaling-up and commercialisation of grassroots innovations" (STIP 2020, p.32). This process requires a vibrant venture capital landscape that not only provides access to funding in the process of ideation to market but also business support services. Within the Indian context, the majority of venture capital funds are private sector-owned and concentrated in metro cities.[76] Though there are government-driven funding mechanisms such as the National Research Foundation (NEP 2020) and the Technology Acquisition Fund (NAP 2018) that focus on indigenous R&D and technology acquisition through public-private partnerships, it is still ommercial that the absence of venture capital investment thwarts innovation in India (NITI Aayog, 2021).

6.4.2 Knowledge-Based Institutions

From the view of knowledge-based institution respondents (see Figure 25 below), it is evident that in general the majority of respondents view all policy instruments as 'Highly Successful' and 'Successful'. About 11% of respondents indicated 'Government procurement' as an unsuccessful demand-side measure. The same percentage of respondents reported the supply-side finance instruments 'Government-backed venture capital' and 'Donor funds' as unsuccessful. At the same time, 37% of respondents stayed 'Neutral' for 'Donor funds', which might be because they are not aware of donor funds as donors (multilateral organizations) generally do not directly fund KBIs but rather work in close partnership with intermediaries and the government to support industry.

FIGURE 25: Success of policy instruments - Knowledge-based institution



In terms of policy success, the supply-side service measure of 'ICT accesses emerges as a clear winner with a total of 85% of KBI respondents reporting it as 'Highly Successful' and 'Successful'. The response of KBIs for 'ICT access' is convergent with that of industry and has been explained in the previous section. This is followed by the supply-side financial policy measure 'Research grants' that has been reported as the second most successful by 80% of respondents.

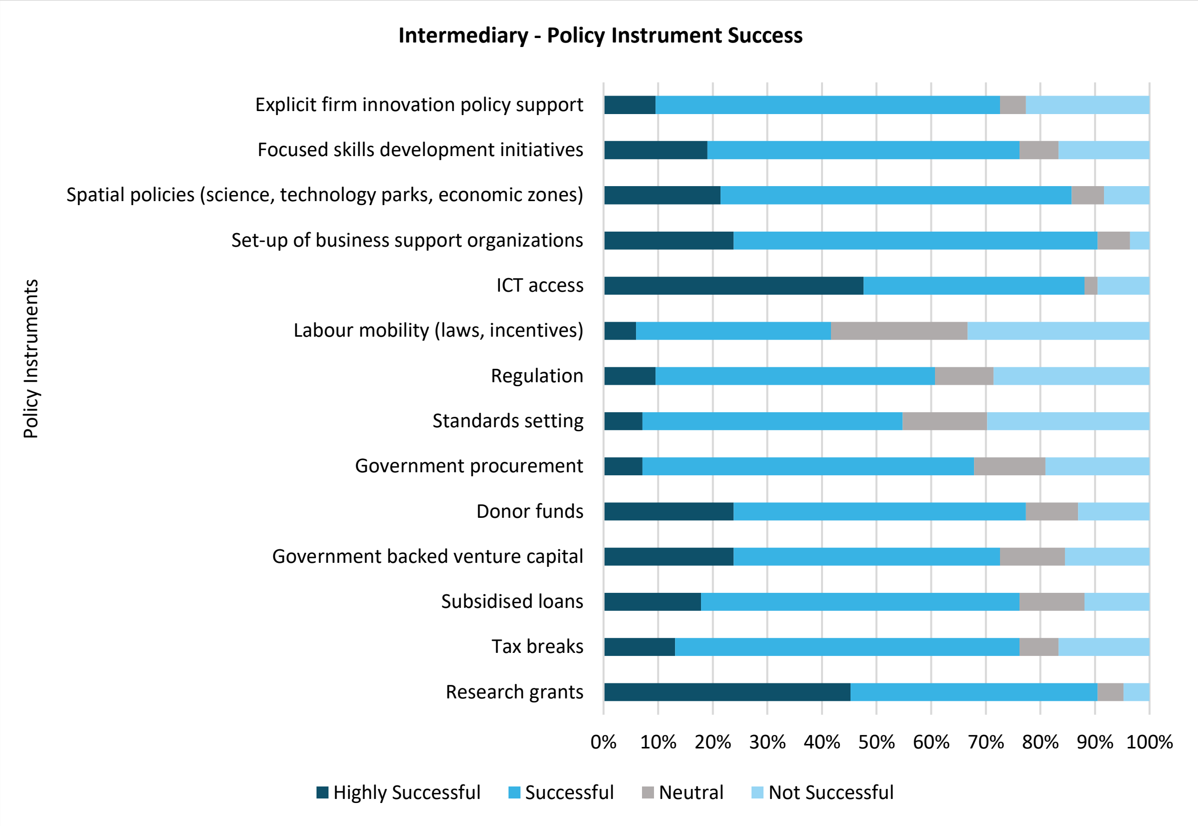
The success of 'Research grants' as a policy instrument can be attributed to the funds received from the government under various programmes such as the "National Mission on Education through Information and Communication Technology" (NMEICT), "National Supercomputing Mission" (NSM), "Financial Assistance Scheme for setting up of Electronics and ICT Academies", and the financial support "Scheme for Promoting R&D in the Field of Convergence Communications & Broadband Technologies" (CC&BT). These programmes aim to ommerciali research and intellectual property (IP) development in the country.

6.4.3 Intermediary

Intermediaries report all policy instruments as 'Highly Successful' and 'Successful' (see Figure 26 below), except for the demand-side measure of 'Labour mobility (laws, incentives)' with 33% of respondents reporting it as unsuccessful. Labour mobility refers to the ability of a worker to move across jobs, occupations and sectors to take advantage of new opportunities but barriers to mobility make these moves costly.

[76] Government-backed venture capital funds include: SBI Capital Markets Ltd. (SBICAP), Canbank Venture Capital Fund Ltd. (CVCFL), IFCI Venture Capital Funds Ltd. (IFCI Venture), and SIDBI Venture Capital Limited (SVCL). Source: https://www.indianweb2.com/2015/01/13-govt-venture-capital-firms-for 14.html

FIGURE 26: Success of policy instruments – Intermediary



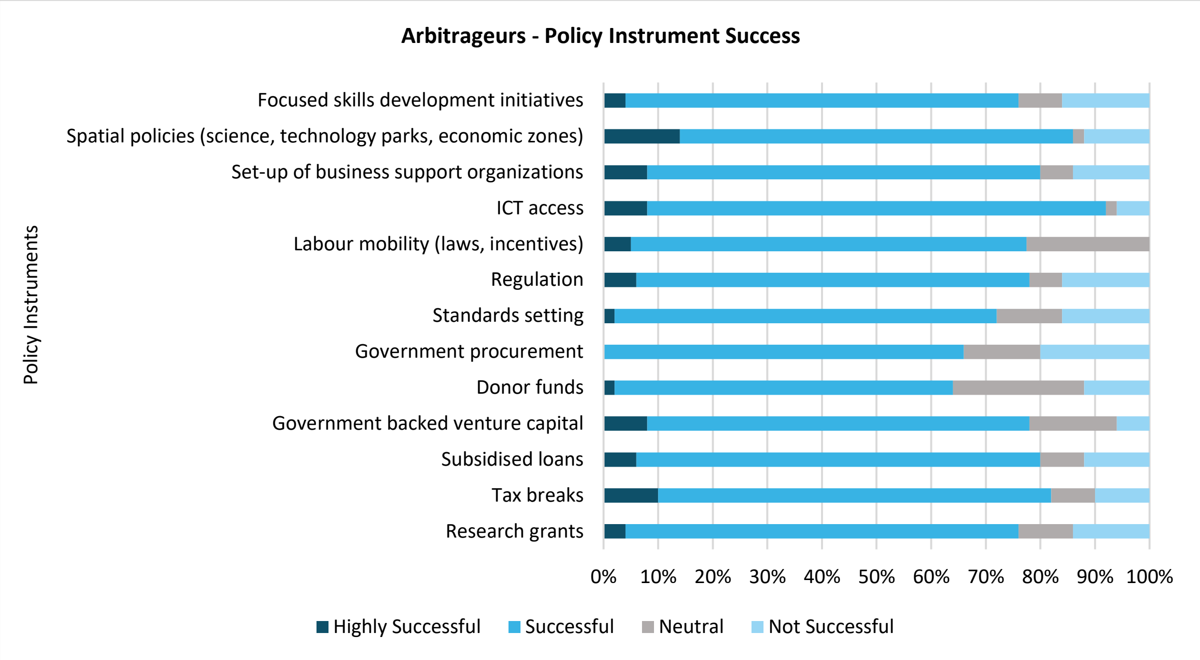
These barriers include time-consuming job searches; skill mismatches, non-transferable skills, rigid employment policies such as employment protection legislation, restrictive immigration systems, and high recruitment costs. Better policies can reduce rigidities in the labour market and address these barriers (Testaverde, M. et al., 2017). More specifically, rapid technological change in ICT job roles and the proliferation of Industry 4.0 technologies has impacted the labour mobility in the ICT sector. There is a need to invest in people's capabilities to enable them to thrive in a digital age, which will also help in overcoming barriers to labour mobility (ILO, 2019).

The second and third most unsuccessful demand-side measures reported are 'Standards setting' (reported unsuccessful by 30% of respondents) and 'Regulation' (reported unsuccessful by 29% of respondents). The National Telecom Policy of India (2012) intends to increase standardisation and intellectual property creation but there is no comprehensive legal framework and regulatory body to deal with private standards setting in India (Bhardwaj, 2013). The predominant issues in standards setting are nondisclosure of IP, manipulation of the standard setting process and fairness of IP policy, which can be taken care of by a carefully drafted IP policy (Bhardwaj, 2013). The convergence of various technologies poses several policy and regulatory challenges in the areas of: industry structure, market power of firms, pricing of products and services, interconnection of networks, radio spectrum management, intellectual property rights, data privacy and security (V. Sridhar 2020).

In terms of policy success, 'Research grants' and 'ICT access' are deemed as 'Successful' by 90% and 88% of respondents respectively. The response of intermediaries for these two instruments is convergent with that of industry and KBIs and has been explained in the previous section. Another policy instrument that is deemed as 'Highly Successful' and 'Successful' by 90% of intermediaries is 'Set-up of business support organizations'. This is convergent with the functioning of industry associations which is to liaise with the government in advocating solutions for the challenges faced by industry. They work closely with the government on policy issues, interfacing with thought leaders, and enhancing efficiency, competitiveness and business opportunities for industry through a range of specialised services and strategic global linkages. They also provide a platform for consensus-building and networking on key issues (CII, 2022).

6.4.4 Arbitrageurs

FIGURE 27: Success of policy instruments – Arbitrageurs



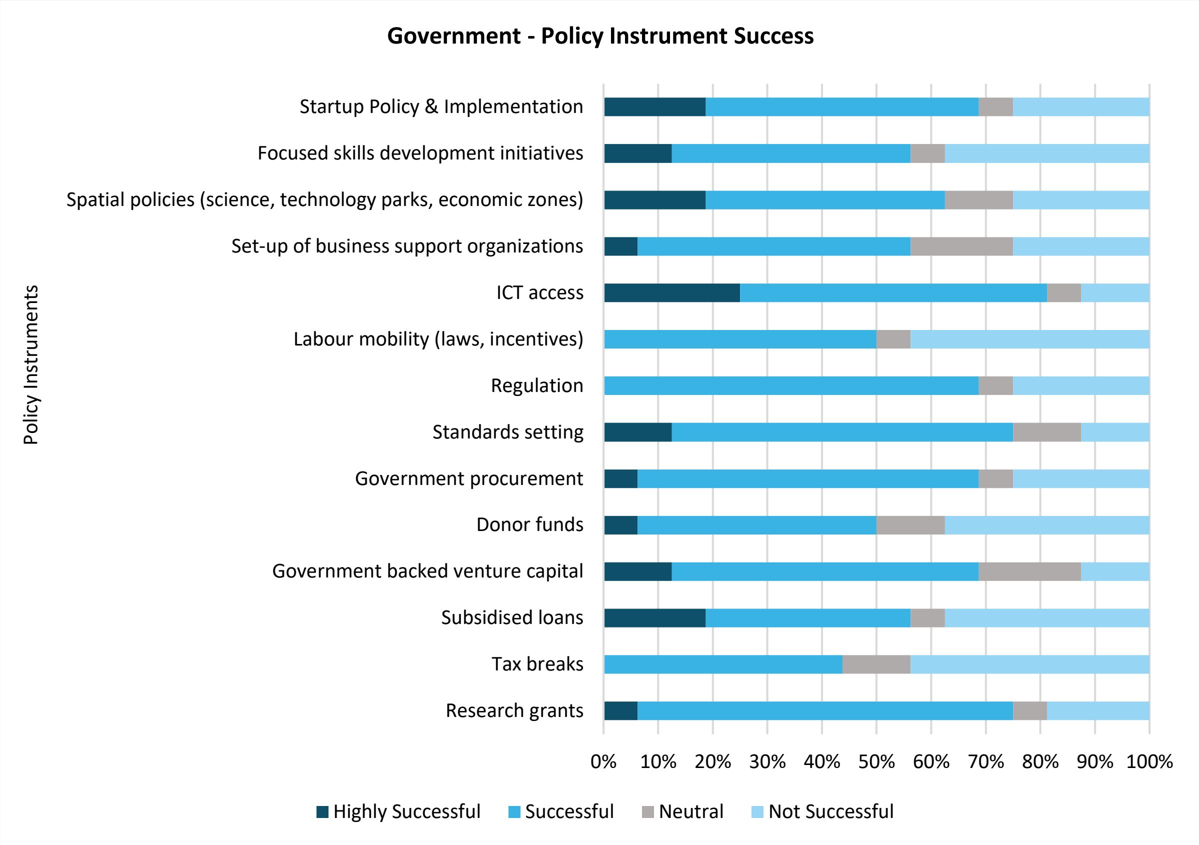
The next actor perspective on the relative success of policy instruments is that of arbitrageurs (Figure 27 above). Again, the majority of the policy instruments are reported as 'Highly Successful' and 'Successful' with the most successful being 'ICT access'. This mirrors the view of KBIs and that of industry. The two demand-side measures, namely 'Labour mobility laws and incentives' and 'Government procurement' have been reported as unsuccessful by 10% of respondents each. These observations converge with that of intermediaries in terms of 'Labour mobility laws and incentives' (explained in the previous section) and with KBIs, with regards to 'Government procurement'.

India is lagging in several indicators related to the assessment of the state of procurement practices (OECD, 2019) namely: "strategic leadership, efficiency, the procurement process's openness, and the legislative framework in place, including subordinate legislation, model documents, and general contract conditions" (Nair, 2021: p.1). There is a lack of a comprehensive central legislation solely governing public procurement in India. The current public procurement regime comprises a framework of overlapping administrative rules and regulations, sector-specific guidelines and state-specific legislation (BTG Legal, 2021). The Government of India implemented the General Financial Rules (GFR) as its core procurement framework in 1947 which was only updated in 2017. The absence of a central procurement regulation enabling procuring authorities with scope to tweak guidelines and contract formats, leads to confusion on the one hand and rigidity on the other. Consequently, different agencies may even prescribe varying qualification criteria, financial terms, selection procedures, etc., for similar public sector work. Further, the government has been making efforts to ensure transparency and fairness in the public procurement system. In 2012, the Government of India introduced the Public Procurement Bill and the introduction of a new legislation to govern how the government buys goods and services from the private sector is one of the proposed solutions to public procurement problems (Roy and Uday, 2020). Minister of Finance, Mr Arun Jaitley, in his 2015-16 Budget Speech advocated the same and stated, "Malfeasance in public procurement can perhaps be contained by having a procurement law and an institutional structure consistent with the UNCITRAL Model. I believe parliament needs to take a view soon on whether we need a procurement law, and if so, what shape it should take." (Paragraph 72). The present government is yet to introduce the bill.

6.4.5 Government

The last actor's perspective on the relative success of policy instruments is that of the Indian government (Figure 28 below). Again, 'ICT access' emerges as the most successful policy with a total of 81% of government respondents reporting it as 'Successful' (after combining 25% 'Highly Successful' and 56% 'Successful' responses), while 75% of government respondents see 'Research grants' and 'Standards setting' as 'Successful'. The demand-side measures of 'Labour mobility (laws, incentives)' and 'Tax breaks' have been reported as unsuccessful by 44% of government respondents each. Labour mobility challenges have been explained in the previous sections. The importance of 'Tax breaks', however, is ommercial by the NITI Aayog as a means to promote business sector R&D.

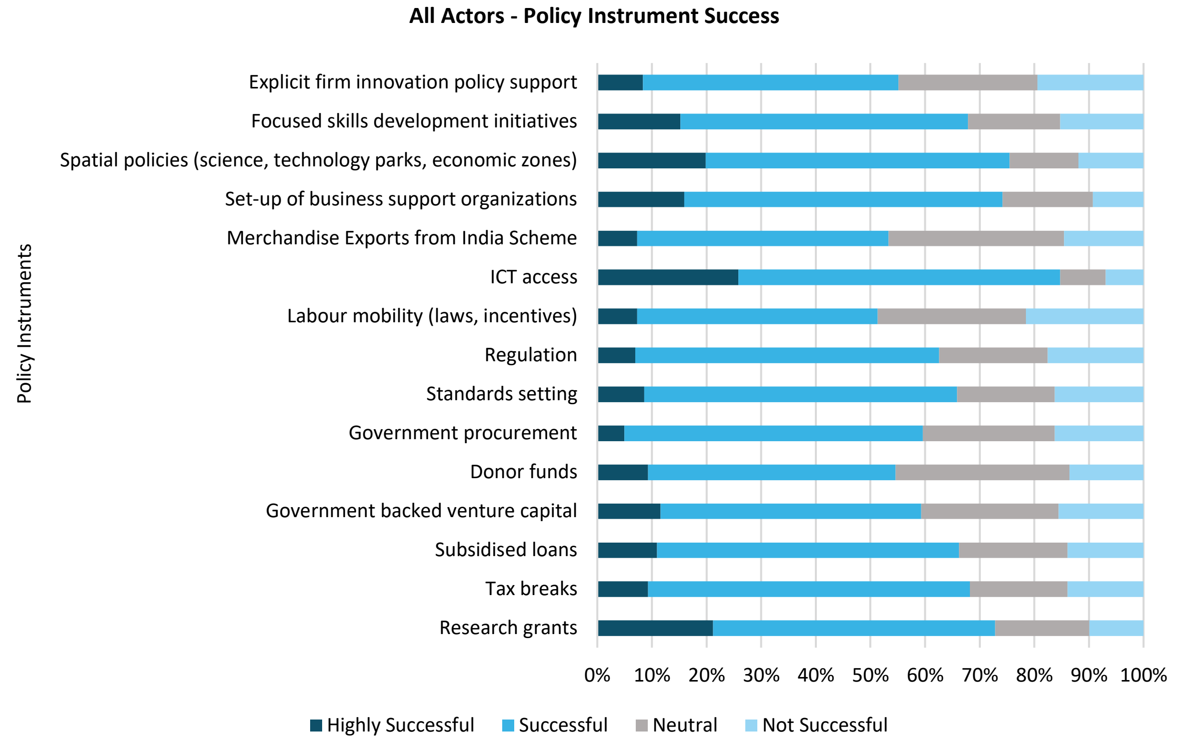
FIGURE 28: Success of policy instruments – Government



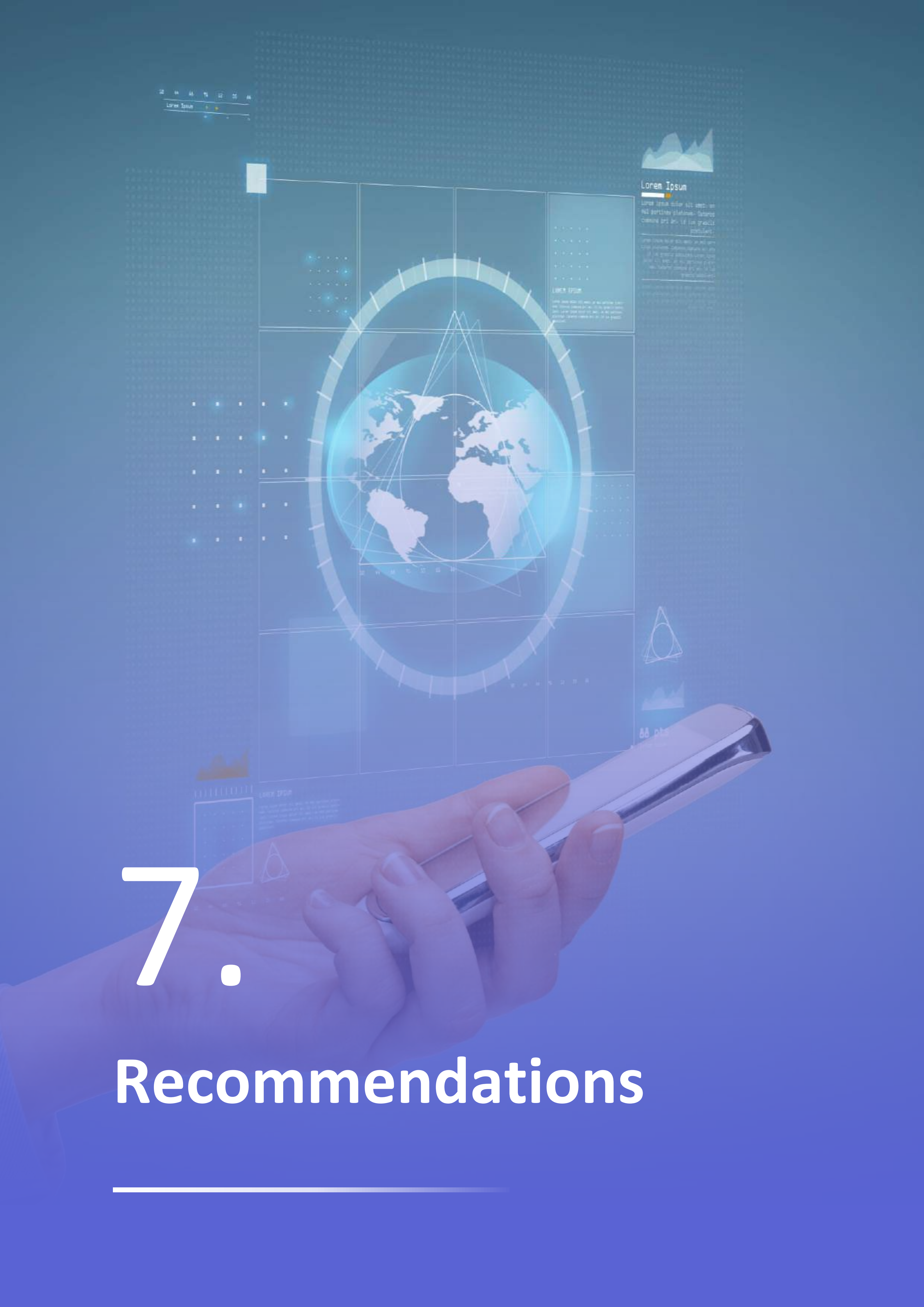
The government could focus on specific areas under which top R&D-intensive domestic firms are eligible for tax incentives (NITI Aayog 2021). This is echoed in the STIP 2020 which stipulates that in order to incentivise investments in STI, there is a need to boost "fiscal incentives for industries investing in STI through incremental R&D-based tax incentives, tax credit for investing in facilities for commercialisation, tax holidays, tax waivers, target-based tax incentives for specific domains, tax deductions, expatriate tax regimes, and remodeling of patent box regime, etc" (DST, 2020: p.21).

6.4.6 All Actors

FIGURE 29: Success of policy instruments - All actors



Summarising the above results, the most successful policy instruments reported by all actors in the ICT sector are 'ICT access' at 85% in total (59% reporting it as 'Successful' and 26% reporting it as 'Highly Successful'), followed by 'Spatial policies' at 75% in total (55% reporting it as 'Successful' and 20% reporting it as unsuccessful) and 'Set-up of business support organizations' at 74% in total (58% respondents reporting it a 'Successful' and 16% reporting it as 'Highly Successful') while the most unsuccessful policy instruments include the demand-side measures of 'Labour mobility (laws, incentives)' at 22% and 'Regulation' at 18%. The viewpoint on labour mobility has been explained in the sections above whereas the viewpoint on 'Regulation' is reflective of the variables such as 'Restrictive public/government regulations' and 'Lack of higher resolution regulations' that are reported as prominent barriers to innovation faced by all actors in the ICT sector (see Table 14: System-wide barriers to innovation).



7.

Recommendations

Recommendations

Literature on innovation policy draws attention to the complex and heterogeneous nature of the policy instruments at hand. It captures the growing interest in understanding the effects that different policy instruments have on innovation performance, how (combinations of) individual instruments interact with market mechanisms and the overlapping or complementary effects that can be associated with different policy instruments within systems of innovation (Borrás and Edquist 2013; Izsák, Markianidou, and Radošević 2013; Mohnen and Röller 2001). This diversity reflects the complexity of innovation systems which entail a series of elements or subsystems that can reinforce, but also block each other (Hekkert et al., 2007; Kuhlmann and Arnold 2001). The underlying innovation-related policy objectives or policy domains subject to specific policy interventions can be grouped around one or more of the following objectives (Borrás and Edquist 2015):

- Support investment in research and innovation
- Enhance innovation competences of firms
- Increase adoption of Industry 4.0 through digital transformation in the ICT sector
- Support services for innovating firms
- Competence building through individual/ organizational learning, involving formal/informal education and training
- Demand-side activities involving the creation of new markets
- Provision of constituents or supporting the development of agents within the system
- Enable integration of MSMEs into GVCs
- Strengthen linkages within innovation systems.

This list is not exhaustive but helps to illustrate the ramifications of the policy-decision tree around innovation and industrialisation. Addressing these policy problems calls for a portfolio approach in which a combination of instruments simultaneously targets several objectives and groups of policy problems (Izsák, Markianidou, and Radošević 2013; Nauwelaers 2009).

Policy instruments result from policies aimed at facilitating different forms of innovation, including products or services, which denote the acquisition/ development of new proprietary technologies protected by patents or other forms of intellectual property rights (IPRs); yet some others are closer to business process innovations in the form of changes in operations (manufacturing techniques, optimisation of workflows and process re-engineering), product development, business process development, marketing and sales, procurement, logistics and distribution, as well as organizational innovation through changes in administration and management. Whereas some policies aim to support forms of innovation with clear and rapid market potential, some others aim to address more upstream issues with no immediate commercial value.

The possibility of combining policy instruments is what makes innovation policy systemic (Borrás and Edquist 2013). However, finding 'optimal models' for the combination of instruments, otherwise interpreted as one-size-fits-all solutions, is problematic; significant differences result from framework conditions but also from the 'quality' of implementation (Flanagan, Uyarra, and Laranja 2011), the degree of maturity reached by certain agents or the innovation system as a whole (Izsák, Markianidou, and Radošević 2013), and even the particular governance structures around innovation (Dutrénit et al., 2010). Moreover, identifying the impacts of individual innovation policy interventions on social and economic outcomes is extremely difficult. There is a complex chain of direct and indirect, vertical and horizontal effects, and the ultimate results may only be perceptible many years after implementation (Padilla-Pérez and Gaudin, 2014; Santiago and Natera, 2014).

Finding an optimal innovation policy mix is not a one-off exercise, but a continuous process that adjusts to the dynamics of an innovation system. The formulation of effective policy is therefore a highly complex affair. Table 15 highlights short-, medium- and long-term recommendations based on the analysis conducted.

TABLE 15: Policy recommendations

Observation	Implication	Recommendations
Fragmented system-wide actor information	Better access to public goods in order to have an up-to-date understanding of who's who and who's where in the IICTSSI. Robustness and credibility of data shared at the system level.	Need to integrate and standardise national actor databases with respect to the IICTSSI. • Review and consolidation of existing data. • Regularly update centralised sectorial database. • Purpose driven platform to be developed in PPP approach (beyond search engine, for example Startup India, IRCTC - Indigo). • To be owned by government and managed by institutions with access by all major institutions (market driven). • Integrated feedback mechanism for improvement (stakeholders at all levels).
Need to improve target response rate, especially in the case of Government actor group	Better clarity in systems analysis for evidence-based policy craft incorporating longitudinal benefits of data collection	• Institutionalise the IICTSSI Survey within a national institution with top-down mandate. • Make the IICTSSI Survey a mandatory census (4 years) and linked to the national database. • Targeted promotion strategy (including use of multimedia and social media, dissemination of value information, creation of ownership, multiple level campaign. • Actor or entity (state level, district level etc.) competition for response rate. • Incentivization through a sense of belongingness, continuity and follow-up. • Acknowledging and lauding of contributions by leading institutions - creation of champions. • Data collection driven regional outreach initiatives. • National level agencies to be coordinated and partnered with. • Planning and onboarding to make utility of champions. • Upstream driven sensitization approach.
Need for better institutional coordination between regions / clusters.	Ease of skills and knowledge flow between and sharing of best practices between actors.	• Commonly agreed structured framework for joint activities • Creation and transmission of information using contemporary multimedia resources. • Sharing of failures and lesson learning. • Regular meetings in person; quarterly webinars. • Virtual dissemination of Data Information Statistics and Knowledge (DISK). • Creating champions for systematic coaching of the sectors taking into account equally successes and failures. • Make use of middle-level executives. For example, LinkedIn creator accelerator programme (CAP).
Better awareness of policy terminology (SSI) across system actors	Across the board understanding	Have a standard definition in all documentation. • Present definition in national government bulletin. • Standardization of terminology used in policy/national documentation. • Outreach to industry via industry associations. • Development of impact driven byte size content dealing with core terminology and widely disseminated using multimedia in multi languages (30 sec short).

Lack of understanding by actors of each other's role within the IICTSSI	On clear understanding of actor roles and responsibilities within a system there is the increased ability for them to reach out to each other. With the focus being impact on the directionality of actor relationships to become more bi-directional.	• SSI should be an integrated component of national events • National innovation event (every 2 years bringing together users, producers and service providers for innovation). It can be linked to National Science Week (10 best projects). • An integrated platform linking institutions and their services • Developing actor level content using multimedia - easily accessible and easily digestible. For example, fail fast fail safe (moral of the story). • Learn, un-learn, and thinkers and be future relevant. • Culture of innovation (create a mascot). • Promote adoption of ISO 56002 (2019). • Incorporation of Theory of Inventive Problem Solving (TRIZ) within the sector. • Creation of an innovation indicator assessment scheme for all contributing actors. Participation and access to assessment score can be used to leverage benefits. Catching them young (tinkering labs, startup kits).
Industry modes of interaction that require attention: **Intra:** Despite user-producer relationship between IND actors there are few linkages in terms of seminar/trainings, joint research & joint ventures **Inter:** **IND - GOV** Poor public financing for the ICT sector. **IND - KBI** Conversion of joint research activities into innovation output is less along with low flow of funding **IND-INT** Low level of co-publishing activities. **IND-ARB** Few linkages in terms of seminars/ trainings and recipient of funding.	Low innovation activity in the ICT sector due to lack of public funds for the industry. Government to better disseminate information on funds amongst industry players, in particular MSMEs. Low engagement with KBIs. Impacts generation of applied research. Lack of codification of knowledge. Impedes financial institution's ability to assess risk in line with rapid technological change.	**Intra** • Incentivize firms for strategic partnerships to develop digital competencies. • Establish Global Capability Centers at regional level to strengthen local ecosystem. **IND-GOV** • Leverage the use of ICT in improving governance & thriving digital economy. • Like domestic R&D spend, institutionalize digital spend for adoption of basic digitization. • Scale-up industry-government partnerships for cross-training programs. **IND-KBI** • Enabling co-creation strategy for innovation & IP development. **IND-INT** • All avenues of dissemination of information and knowledge must be leveraged, in line with the target audience. **IND-ARB** • Better connect financial institutions to knowledge dissemination activities using industry associations as a conduit. • Explore Digital Revenue Streams to boost digital efficiency.

Knowledge-based institutions modes of interaction that require attention: **Intra:** Few interactions in the form of secondments & low innovation outputs. **Inter:** KBI-IND Few linkages through joint research, co-publishing and recipient of funding. **KBI-INT** Few joint research activities & low conversion along with recipient of funding **KBI-ARB** Few seminars/training activities.	Limits commercial adoption and application of new technology KBIs seen as a wider knowledge resource. Venture capital and angel investors better informed of recent research and technology shifts. Graduates are more cognizant of how to access funding for ideation to market.	**Intra** • Incentivize KBIs for collaboration & skilling in exponential technologies. • Create forums for interactions, meetings, seminars, and recruitment activities with respect to the ICT sector. **KBI-IND** • Promote research in local languages through advanced computing technologies. • Foster partnership with Massive Open Online Coaching (MOOC) providers on digital projects. • Similar Initiatives like QuEST Global IIoT CoE should be replicated (Joint Initiative between QuEST Global & New Horizon College of Engineering, Bengaluru) • Enable a KPI tracking system for value generation/technologies developed. • Facilitating publishing of technology research from the point of view of IPR and other legalities. **KBI-INT** • Intermediaries can bridge between KBIs and industry and be a facilitator of training and upskilling. • Utilising intermediaries for increasing visibility and outreach of research being done by Indian KBIs to help facilitate demand for upskilling. Intermediaries can be conduit for assessing needs, quality and demand of skills required by industry. **KBI-ARB** • Educating financial institutions and their assessors in line with new technological trends as well as changing industry needs. • Promote sponsored training programs & offer scholarships/stipend to students for research in ICT.
Intermediary modes of interaction that require attention: **Intra:** Limited joint research and co-publishing activities. **Inter:** INT-IND Few interactions through recipient of funding & joint research **INT-KBI** Despite joint research & co-publishing, innovation outputs are less.	Lack of codification of knowledge together with industry Better utilization of incubators and start-ups as an industrial resource.	**Intra** • Formulate R&D cum Data Engineering forums for boosting joint initiatives. • Creation of a joint forum across intermediaries to discuss the emerging technologies and business opportunities. **INT-IND** • Regulatory institutions in collaboration with industries develop/adopt ICT technologies in digitalization of existing regulations (GST, SEBI). • Take into consideration the value addition of stakeholders in the formulation of new projects/ activities, (not as a second thought but from the onset). **INT-KBI** • Incentivize ISTC's to establish strategic cells in KBIs for facilitation of knowledge sharing and provision of business support services for ideation to market.

Arbitrageurs' modes of interaction that require attention: **Intra:** Less user-producer relationships **Inter:** Overall, there are few linkages with other actors. **ARB-IND** Few linkages through user-producer relationships & recipient of funding **ARB-KBI** Few linkages in terms of joint research activities **ARB-INT** Few interactions through joint research, co-publishing & recipient of funding	Arbitrageurs are isolated as actors, and they can't perceive the importance of their own role in the ICT sector.	**Intra** • Have regular fora addressing the areas of future technology trends skills and with inclusion of other system actors. • Creating a pool of funds to support studies and activities pertaining to future technology trends and transformation of the ICT sector. Thus, enabling them to better assess the risk and returns of the future of investment in the sector. **ARB-IND** • Promote Investment in building digital capabilities & services. (Eg. HCL - Deutsche Bank = cloud-based digital cheque platform). **ARB-KBI** • Similar Initiatives should be conducted like IIT Delhi & SBI collaborating together for digital technology solutions. **ARB-INT** • Co-investment for block chain specific CoE labs & digital incubation centers.
Latent barriers - All Actors • Industry 4.0 (Lack of understanding of I4.0 technologies; lack of access to I4.0 technologies; cost of I4.0 technologies; and lack of infrastructure for I4.0) • Policy and function (Lack of legal framework; restrictive public / governmental regulations; lack of clear national innovation strategy; and lack of higher resolution regulations) • ICT Knowledge & Stocks (Rate of access to ICT; ICT capacity; lack of technology-Technology gap; and lack of information-Knowledge gap) • Human Capital (Lack of technically trained manpower; quality of technically trained manpower; and lack of willingness to share knowledge) • Finance (Lack of Finance, Innovations Costs (Too High), Excessive Perceived Economic Risk		**Industry 4.0** • Scale-up more number of Data Centre Parks/Cloud Infrastructure across the country. • Like Electronic Manufacturing Clusters, promote Software Development Clusters in Tier 2/3 cities. **Policy and function** • Need for inter-sectoral committees with top-down approach for effective functioning. • Simplify policy information for better comprehension by industry particularly T2 and T3. • Use industry associations for outreach. **ICT Knowledge & Stocks** • Create demand for software penetration across the country. **Human capital** • Reskilling & talent accelerator initiatives to promote advance learning among the workforce. • Scale-up more digital literacy missions. **Finance** • Institutionalize a mechanism to encourage private financing in the form of private equity/VC and special interventions for attracting global investors.
Unsuccessful policy instruments from the perspective of Industry: • Govt. backed venture capital • Labor Mobility • Regulations	Strengthen and focus delivery of policy to address specific gaps	• Scale-up digital investments by foreign venture capital firms. • For regulating a high-risk environment, need of central govt. led sandbox approach with involvement of sector-specific actors. • Periodical sector-specific skills assessment & driving life-long learning strategies.

Unsuccessful policy instruments from the perspective of KBI: • Govt. backed venture capital. • Govt. Procurement • Donor Funds	Strengthen and focus delivery of policy to address specific gaps	• Standardize government procurement as per best international practices. • Establish new technology funds fostering industry-academia research. • Partnering with global agencies to access funds for re-skilling & up-skilling. (Collaborative learning ecosystems)
Unsuccessful policy instruments from the perspective of Intermediary: • Labor Mobility • Standard Settings • Regulations	Strengthen and focus delivery of policy to address specific gaps	• Establish a readiness framework for ensuring effective implementation of new regulations. • Strengthening of open data community platforms & aligning with NIST Cybersecurity Framework. • Need to review existing occupational standards for skill development. • Need of PLI scheme for software-products & specific interventions to increase MSME coverage under PLI Scheme.
Unsuccessful policy instruments from the perspective of Arbitrageurs: • Labor Mobility • Government Procurement • Standard Settings	Strengthen and focus delivery of policy to address specific gaps	• Encourage MSMEs in participating government contracts by embedding special focus on innovation. • Promote Intrapreneurship schemes for employees and increase employee retention.

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9.

Annexes

Annexes

9.1 Annex 1 – Sample size calculation

- **Overall sample sizes** for both firm level and sectorial system of innovation surveys are determined by the degree of stratification of the sample. The overall sample size depends on the decision of the sample size for each level of stratification.
- **Determining the desired sample size**: Desired sample size from a particular state, which will represent the population (total production units), is calculated through the formula developed by Cochran (1963).

  $$SS = \frac{Z^2 * p * (1-p)}{e^2}$$

  Where:

  Z = Z value (e.g., 1.96 for 95% confidence level)
  p = percentage picking a choice, expressed as decimal (.5 used for sample size needed)
  e = margin of error, expressed as decimal (e.g.,.05 = ± 5%)
- **Margin of Error** – It is defined as the range of values below and above the sample statistic in a confidence interval. It is a measure of the variability of sample statistics, and it is used to indicate the level of precision of the sample estimate. It is typically expressed as a percentage of the total sample size and is calculated by taking the standard deviation of the sample and dividing it by the square root of the sample size. Margin of error for the sectorial survey sampling is ± 5%.
- **Confidence Level** – It is the proportion of sample, which will represent the population, given the level of precision or confidence interval. A 95% level of confidence has been taken, which shows that 95 out of every 100 samples will have true population value within the level of precision.
- **Correction for Finite Population**: If the population is small then the sample size can be reduced slightly. This is because a given sample size provides proportionately more information for a small population than for a large population. The sample size obtained for different states is based on the formula –

  $$New\ SS = \frac{SS}{1 + \frac{SS-1}{pop}}$$

  Where: pop = is the number of production units in a state (finite population)

A convenient sample was chosen for each actor category and contact details were verified through the ASI and CMIE databases.

9.2 Annex 2 – NIC code classification

NIC 2008 Codes & Its Description (Divisions and Groups)	
Division 61	**Telecommunications**
Group 611	Wired telecommunications activities
Group 612	Wireless telecommunications activities
Group 613	Satellite telecommunications activities
Group 619	Other telecommunications activities
Division 62	**Computer programming, consultancy and related activities**
Group 620	Computer programming, consultancy and related activities
Division 63	**Information service activities**
Group 631	Data processing, hosting and related activities; web portals
Group 639	Other information service activities

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